The Archaeology of Furnace Falls:

A Mitigation Report on the Use of GIS, GPS & LIDAR for the Definition & Documentation of Furnace Falls Dam, Spillway, Weir & Channel

Stanhope/Netcong
Morris & Sussex Counties, New Jersey

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Final Report to NJDEP - June, 2004

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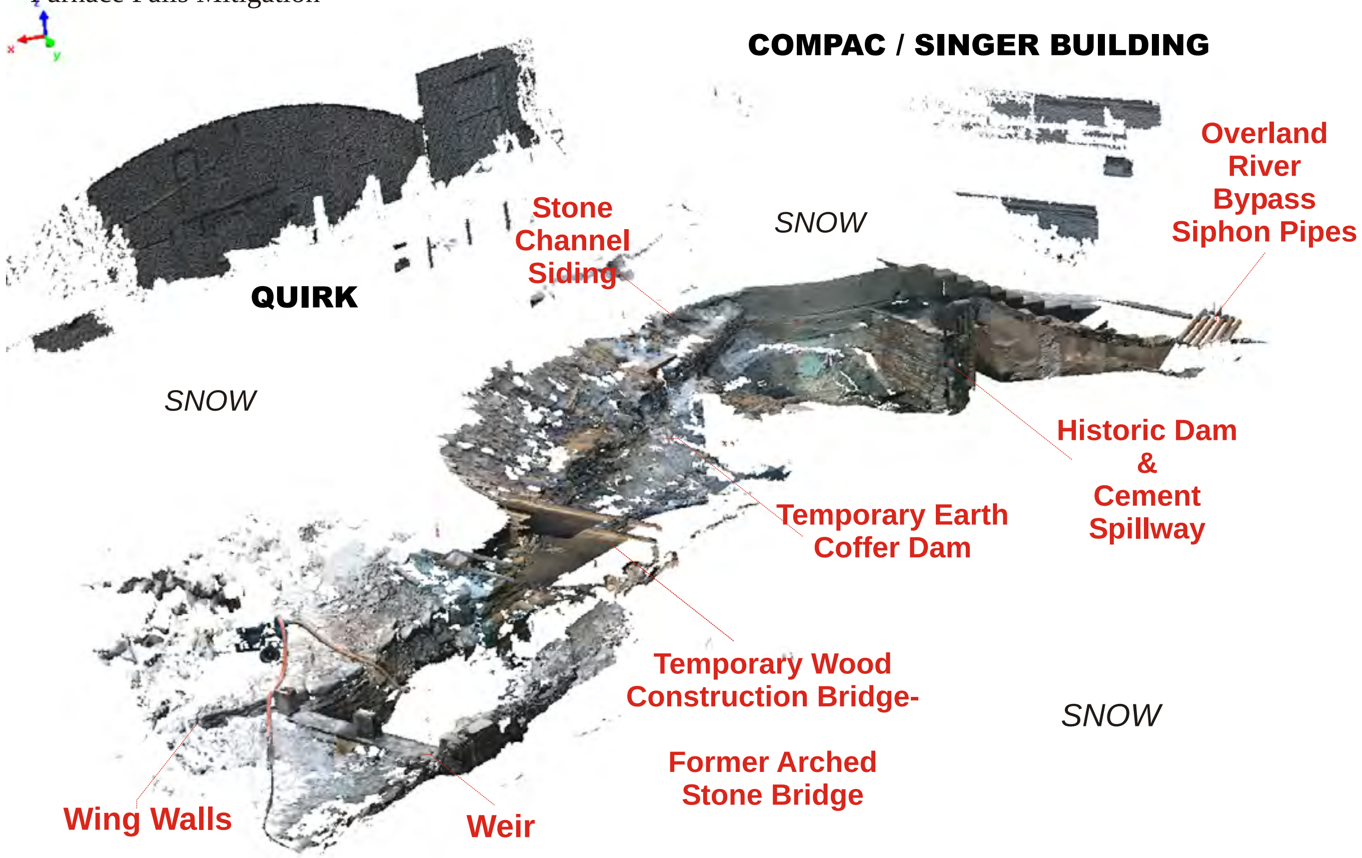

The Archaeology of Furnace Falls

Synopsis

By
Joel W. Grossman, Ph.D.

This report documents the deep winter rescue excavation of historic remains within the Compac Corporation property at Furnace Falls on the Musconetcong River in Stanhope/Netcong, New Jersey. It was undertaken in January, 2004, with the objective of mitigating the loss of National and State Register eligible archaeological resources during unavoidable repair work.

The modern Compac Corporation facility was built upon top of earlier historic properties. These included the post-1830 to 1840 Musconetcong Iron works as well as the later early 20th century production facilities of the Singer Sewing Machine company.

The earlier Civil War era foundry had been built adjacent to, and hydrologically integrated with, the Morris Canal. Associated historic features visible on the site included a massive cut stone retaining wall, an arched cut stone bridge over the Musconetcong, a feeder spur and reservoir from the Canal to the foundry and ill defined submerged structural features within the river channel.

In the summer of 2000, heavy flooding led to the accumulation of debris against the 1874 stone bridge at Furnace Falls Pond, breeching and destabilizing it as well as an associated 20th century spillway below it leading into the channel beneath the Singer/Compac Corporation building. Emergency repairs were mandated by the New Jersey Department of Environmental Protection (NJDEP). The remains of the cut stone bridge were removed as a health and safety hazard and temporary sheeting installed to prevent further destruction due to flooding.

During this work, it became apparent that the emergency dam remediation could disturb or damage significant historic components associated with the Civil War era foundry. In response to this threat, the NJDEP Office of Historic Preservation mandated that Compac Corporation, as owner of the property, develop a mitigation program. The purpose of this plan was to evaluate and then protect and/or document potentially surviving historic elements within the path of the mandated construction and repair effort.

In April 2002, Compac Corporation retained archaeologist Joel W. Grossman to develop a two-part background sensitivity study and mitigation plan aimed at reducing impacts to the its property, using engineering and redesign to circumvent identified components of the historic complex wherever possible. This plan became the basis for redesign of the planned dam remediation work.

Under the lead of Langan Engineering and Environmental Services, Inc., initially proposed deep trenching through the historic site and steel sheeting operations across the channel were replaced with an overland river bypass system and the movement of the sheeting out of sensitive areas. In addition, the 2002 mitigation plan (Grossman 2002) identified remaining areas subject to unavoidable impacts from the proposed dam and flood control work. These areas were then targeted for staged archaeological investigation and mitigation prior to construction. Finally, formerly buried historic wing walls of the 1874 bridge were defined during construction and protected.

The necessary data recovery mitigation took place in two phases.

The first phase involved the exposure and documentation of two near-surface historic features within the Access Road scheduled to be used for the mobilization and movement of heavy equipment and materials into the site. Phase I was undertaken from October 28 to November 1, 2003.

The second phase was developed to be coordinated with the planned diversion and dewatering of the channel as to provide access to both the construction contractor and the archaeologist. Phase II was completed in six days between January 13 and 29, 2004.

The Phase II field excavation exposed four major historic components of the Furnace Falls complex:

- 19th century remains of the 1874 cut stone bridge

- Preserved elements of the historic stone lined channel

- Early 20th century additions to the original dam and channel as part of the state-mandated closing operations of the Morris Canal and related facilities

- Surviving remains of the original 1830 era Furnace Falls Dam. The early stonework was found buried, submerged and preserved beneath the more recent cement cap on the 20th century Singer Spillway across the Musconetcong.

This report summarizes the procedures and findings of this fieldwork. It also describes the first-time deployment of advanced LIDAR radar scanner technology, together with photogrammetry and traditional survey techniques to provide true color 3D documentation of the affected elements of the historic site complex.

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June, 2004

Introduction

Background and Compliance Context

This Phase II Archaeological Data Recovery study reports the investigation and documentation of all sections of the historic Furnace Falls Pond complex impacted by emergency dam remediation work on Compac Corporation property straddling the Musconetcong River in Stanhope/Netcong, New Jersey.

The archaeological field effort covering the dam, weir, spillway and channel took place in two phases, October/November, 2003, and January, 2004. It implemented the recommendations defined in the Furnace Falls Archaeological Mitigation Plan as adopted by the New Jersey Department of Environmental Protection, Historic Preservation Office (NJDEP-HPO), in September of 2002 (Grossman 2002).

The investigation was prompted by cultural resource stipulations of the New Jersey Land Use Regulation Program which controlled the mandated emergency dam remediation work on the flood damaged Furnace Falls Pond complex.

The challenges posed by deep winter conditions and restricted time frame of the field work were addressed through the deployment of several applied technology solutions, namely, single camera Rolleimetric photogrammetry, high resolution GPS datum control receivers and a new generation of true color 3D laser radar hardware and software, LIDAR (Light Detection And Ranging -- see Site Documentation Procedures).

The Mitigation Plan

The 2002 Mitigation Plan consisted of a Phase I background sensitivity evaluation, a GIS-based site definition study of the site's internal structure as well as extent, and recommendations for design alternatives. Its primary goal was to identify, define, evaluate, and, where possible, mitigate any impacts with avoidance through redesign versus excavation. Mitigation through archaeological data recovery was recommended only where avoidance through redesign was not possible.

Undertaken between April and September of 2002, the background study focused of the historical and geographic context of the site and its National and State Register eligibility status.

The initial investigation used both traditional archival and map sources, advanced air photo map and image processing as well as GIS (Geographic Information Systems) to scale and overlay digital copies of historic maps over geo-referenced low level air photo coverage to identify and target the location of potentially sensitive archaeological remains (Figures 8 & 9, Phase I - End of Field letter, p. 3 – see Appendix I).

Scaled reconstructions of historic maps documented that the Furnace Falls dam complex was built as a critical component of the Musconetcong Iron Works (Figure 5). It also showed that its water control and power system was tightly integrated with the hydrology of the Morris Canal and its feeder canal into the foundry (Figures 2, 3 & 4). The GIS historic map analysis served as a planning tool to provide sufficient definition to permit mitigation of potential impacts through redesign and avoidance and target areas of subsurface sensitivity for archaeological documentation.

The final protocol incorporated two major redesign changes to preliminary design concepts, avoiding the potential for additional major impacts to the site from the planned dam remediation work. These design alternatives were developed as an engineering and archaeological collaboration initially between the project engineers, Langan Engineering and Environmental Services, and Joel W. Grossman, Ph.D., the project archaeologist. During fieldwork, these efforts were continued together with the project contractor, Salmon Brothers Construction, so as to address any last-minute discoveries in the field.

The initial engineering plan had proposed to drive a wall of steel sheeting across and through the former cut-stone channel. This component of the construction was redesigned to be moved to the east, closer to Furnace Pond, to avoid impacting the historic former bridge abutment or elements of the cut-stone channel (Figures 39 & 40). The second major design change involved the need to divert the river for construction purposes as well as the archaeological investigation. The initial concept called for a deep open trench to be cut through the north bank to divert the river. The background sensitivity study showed that earth moving and trenching would potentially impact historic resources eligible for the National Register, specifically the Furnace Falls dam.

The prospect of major impacts and costly archaeological fieldwork prompted the Langan Engineering design team to abandon the idea of subsurface trenching. Instead, the team proposed to divert the Musconetcong River overland with heavy pumps or by whatever means the selected contractor suggested. In the end, Salmon Brothers Construction developed an elaborate but passive overland siphoning system that was silent, required no fuel or maintenance and proved capable of both diverting and then lowering the river to provide the archaeologists and construction teams with an access to the channel (Figure 12).

The archaeological investigation of unavoidable impact areas was divided into two phases defined by the interdependence of dewatering, construction and data recovery tasks and scheduling.

Phase I addressed impacts to near surface features within the Access Road leading into the site from Furnace Street. This initial fieldwork was followed by a hiatus of two months to give the contractor time to build and activate the overland river bypass system.

Phase II mitigated unavoidable impacts to the historic channel, surviving bridge abutments and what ultimately emerged as the remains of the original post-1830 dry laid cut-stone dam of Furnace Falls.

Phase I - The Access Road Mitigation

The investigation of the access road impact corridor was undertaken over five days from Tuesday, October 28, to Saturday, November 1, 2003. The GIS-based 2002 background sensitivity study identified the presence of historic near-surface features in the impact corridor of the proposed access road and recommended investigation before the contractor could use the dirt road for heavy equipment and material. The scaled comparison of historic 19th century maps with digitized and geo-referenced air photo coverage targeted two 19th century foundry-related features (see Grossman, 2003 - Appendix I: Phase I - End of Field Letter, p. 4).

One of these, designated Feature 3, was represented by one half of the base of a circular brick chimney 15 ft. wide by 125 ft. high and formally connected to one of the foundry blast furnaces (Figure 5). The second, Feature 2, was a near surface rectangular mortared stone base or foundation related to a second foundry furnace (see Grossman, 2003 – Appendix I: Phase I - End of Field Letter, p. 5).

The coordinates of the two features within the roadway were extracted with GIS software and then measured off on the ground. The blast furnace chimney base was found within 5 ft. of its projected location, the mortared rectangular stone foundation precisely where projected.

Both were exposed and recorded in plan and profile to 1/100th ft. precision with an electronic total station, or computer transit survey instrument, and with single-camera Rolleimetric photogrammetry. Satellite and air photo projection and rectification software was used to assign and imprint State Plane coordinates into each image and then stretch, or “rubber sheet,” them from a perspective view into “overhead” geo-referenced planer views of each feature, reprojected to match their measured coordinate locations and dimensions (See Phase I - End of Field Letter, Grossman, 2003, see Appendix I).

Phase II - The Channel Mitigation

The second phase of the multi-staged mitigation effort, focus of this report, concentrated on the excavation and exposure of unavoidable impacts to surviving historic elements of the channel and spillway. It took place in January, 2004.

After the redesign changes were incorporated to avoid broader archaeological impacts, the final impact corridor measured 180 ft. long by 30-50 ft. wide, stretching out between the eastern wing walls of the former bridge abutment and the lower western end of the cement-covered spillway.

The original Mitigation Plan had called for the documentation of a single profile trench across the eastern end of the channel in the vicinity of the former 1874 cut-stone bridge and for the evaluation and documentation of the depth and structure of the channel. The resultant mitigation strategy was to be integrated with a winter construction schedule and synchronized to begin as soon as the contractor was able to bypass and stem the normal river flow with his overland siphon pipes bypass system. Once accomplished, the archaeologists were to be provided a one week window to expose and record historic elements of the dewatered channel.

The conditions and constraints were clear cut. After the access road was cleared (November 1, 2003,) the contractor had to prepare the site for heavy equipment access, build and activate the overland bypass system, divert and control the river and then lower it through dewatering.

Assuming the water could not be controlled or sufficiently lowered for more than a week, if at all, the archaeology would have to be done within a week as well. It was projected that the archaeological exposure and definition of the historic channel components (weir, dam and channel) would take at least three, possibly four days. That left one to two days to gain grid control as well as to record and document the site.

Normally time-consuming field tasks in this case would have to be accomplished within a narrow one-week window. From the perspective of the archaeological Principal Investigator, the solution not only had to be fast, but it also had to be in true color to be acceptable.

The only technology with the promise of possibly meeting this schedule with the coverage and precision to capture the entire site in mm-precise 3D color was the newest generation of LIDAR (<u>L</u>ight <u>D</u>etection <u>A</u>nd <u>R</u>anging, often referred to as a Laser Imaging Sensor). LIDAR scanners capable of measuring thousands of points per second over hundreds of yards with a precision of 6 mm (ca. 1/100th ft.) had been on the market since 1998. The added capability of 3D color, however, became available only in the summer of 2003.

At the onset of this project, there was only one such hardware and software system available on the market meeting these specifications. That was the recently released 3D Laser Imaging Sensor LMS-Z360i by Riegl Laser Measurement Systems from Austria.

Of all the LIDAR systems available in North America and Europe, this was the only one with an integrated digital camera capable of matching digital color, pixel by pixel, to each coordinate point. This would not only be its first test in archaeology, but according to its vendor, also its coldest.

The new system proved capable, indeed, of addressing the constraints of this deep winter field work. The discovery of the preserved eastern half of the post-1830 cut-stone face of Furnace Falls dam under the cement cap of the Singer spillway during the work shifted the logistics of the investigation to include the full exposure and documentation of the structure, but did not affect or extend the field schedule. Even though a winter storm added an extra day, the site was dewatered, exposed and defined over four discontinuous field days, and then recorded in 3D color to ca. 1/100th ft. precision in six hours on the fifth day of fieldwork (Table I).

As a final task of the mitigation component, and after a week of heavy-equipment demolition in which the contractor had removed the most recent cement wing walls bordering the spillway, the PI returned to the site on January 29th to cross-section and then record the internal construction of the dam's accessible southern end with high resolution digital macro and Rolleimetric medium format 120 mm film images.

Summary of Results

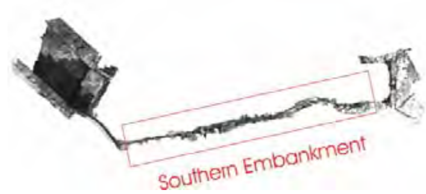
All mandated data recovery tasks were completed as scoped. Both the dam and the associated later cement spillway addition were recorded with 3D color integrated LIDAR, single camera photogrammetry and with high resolution (5.5 mega pixel) macro digital photography and digital video.

The data recovery and mitigation effort provided new information on four major components of the Pre-Civil War Furnace Falls and Musconetcong Iron Works complex.

The Weir: The cement weir with its three vertical grooved cement pods, extending up from the center and ends of a horizontal cement slab at elevation 830+ ft., was a post-1927 addition to the original cut-stone channel and bridge built in 1874 (Grossman 2002). Cutting the 10 ft. wide trench across the width of the channel revealed that the weir was of fragile and insubstantial construction that varied significantly from what had been proposed in Vermeule's 1927 "Canal Closing" blueprints (Figure 41 & 42).

The Channel Wing Walls: The archaeological exposure revealed that the original open, funnel-shaped cut-stone wing walls of the 1874 bridge abutment, or entranceway into the channel from Furnace Pond, had survived. They emerged from the frozen fill and snow as well-preserved multi-course extensions of the stone channel. Both wing walls measured between 9 and 10 ft. from top to bottom, along both sides of the channel. The cut-stone wing walls were preserved in place during construction as well.

These open, funnel-shaped wing walls at the opening of the channel were mirrored by duplicate wing walls on both the east and west sides of the formerly existing 1874 arched stone bridge. Both sides of the eastern opening of the channel were documented with LIDAR, Rolleimetric photogrammetry and high resolution digital cameras.



The Channel: The machine-assisted exposure of the entire southern embankment and three deep profile exposures -- at the east, central and western ends of the channel -- documented at least two forms of coursing -- shallow and deep -- as well as the absolute depth and structure of the southern channel embankment. The entire southern embankment was exposed and recorded with LIDAR and photogrammetry throughout its length, from the weir to the Singer spillway, and then documented with three vertical profile sections to record the structural diversity of the coursing and stonework. No structural elements were exposed or documented on the north side of the channel west of the temporary construction bridge.

The bottom of the channel was demarcated, at its eastern end near the Weir, by the exposure of smooth, debarked logs, between ¾ and 1 ft. in diameter, as footers, or spreaders, under the cut-stone wing walls (Figure 35). The expectation that wooden footers may be present at Furnace Falls was based on the prior demonstration of similar structural elements at the bottom of exposed section of the Morris Canal in Warren County by Brian Morrell 20 years before (Morrell, 1983).

These logs, possibly cedar, were aligned with the long east west axis of the channel and set at elevation 824.5 ft., or between 5.5 and 6 ft. below the top of the post-1927 cement slab weir (830 ft. el.).

The Original Pre-Civil War Cut-Stone Dam:

The dewatering and bypass of the river between the Furnace Pond and the inlet channel under the Singer building revealed the unexpected survival of the eastern - upriver - face of the original cut-stone dam. When laid dry, the cut-stone dam was proven to originally have been at least 16 ft. tall. It was built as a rectangular structure in plan, expanding into a sloped and inverted flat-topped pyramid shape with a 1 ft. wide step, or short terrace, at 5.5 ft. below the top of the stone dam, or ca. 6 ft. below the later 3 to 5 inch thick cement cap that covered it. The dam may possibly pre-date the 1830–1840 initial construction phase of the Musconetcong Iron Works. It was depicted on the 1828 Sykes map (Figure 2). The foundry and the associated massive 16 ft. high stone retaining wall that redefined the local topography of the historic complex appear to have been built contemporary with additions and expansions of the original Morris Canal around 1840 (Grossman, 2002).

As discussed below, the dam and the foundry retaining wall showed similar material and workmanship which contrasted in color and source material (reddish-tan sedimentary stones -- Figure 28 b, c & d) with the gray, metamorphic stone (Figure 35 & 36) used in 1874 for both the arched cut-stone bridge and associated channel and wing wall elements.

The discovery of the stepped, truncated form of the stone dam also added significant new information on the construction and historical development of the Furnace Falls channel and dam complex. The dam façade was archaeologically exposed to its base at ca. 16 ft. below the lip of the cement-clad spillway. This profiling step revealed that the dam had been sliced off at its western side and then been rehabilitated by adding external cement cladding to its outer, downriver face.

Deep Winter Logistics and Staging

The fieldwork for the channel and weir took place during what CNN called the "Coldest January since 1977." Temperatures fluctuated between 0 and 27 degrees throughout the field program.

Identification, definition and documentation of the historic Furnace Falls dam, weir and channel were conducted in three field segments on January 13th-14th, 19th-21st and 29th, 2004. The overall schedule was set by the DEP and the contractor to coincide with low stream levels and to be finished before the onset of the fish spawning season.

Feasibility and timing of the archaeological field effort were determined by

(1) the need to rework the topography bordering each side of the historic channel to provide platforms and access for heavy machinery, and

(2) the need to divert and lower the Musconetcong River.

The channel bed needed to be drained and dewatered both for the archaeological investigation and for the subsequent construction activities.

The archaeological team was mobilized that week and arrived on site on Tuesday, January 14th, for what was planned to be a four day field effort consisting of two days of site clearing and investigation followed by two days of recording with GPS and LIDAR. This schedule was interrupted by an 8-inch snow storm on Wednesday evening which

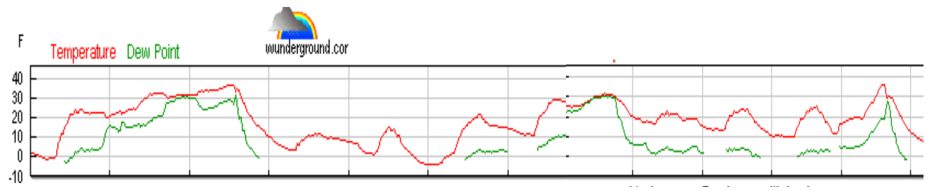
Archaeological Task Schedule
Furnace Falls Dam, Weir and Channel

Table I

Joel W. Grossman, Ph.D., 2004

Day	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
Date		1/12/2004	1/13/2004	1/14/2004	1/15/2004	1/16/2004	1/17/2004	1/18/2004	1/19/2004	1/20/2004	1/21/2004	1/22/2004
Weather	Rain/ ice	Rain	Cloudy	Clear/ Arctic	Snow/ Arctic	Arctic	Arctic	Snow	Clear	Clear	Clear	Rain / ice
Temp.	0 - 23+F	20 - 32 F.	30 - 34 F.	32 - 09 F.	10 - 8 F.	14 - -5 F	-5 - 22 F	10 - 30 F	23 -17+ F.	14 - 23+ F.	10 - 24 F.	35 - 10 F.

CLIMATE CONDITIONS



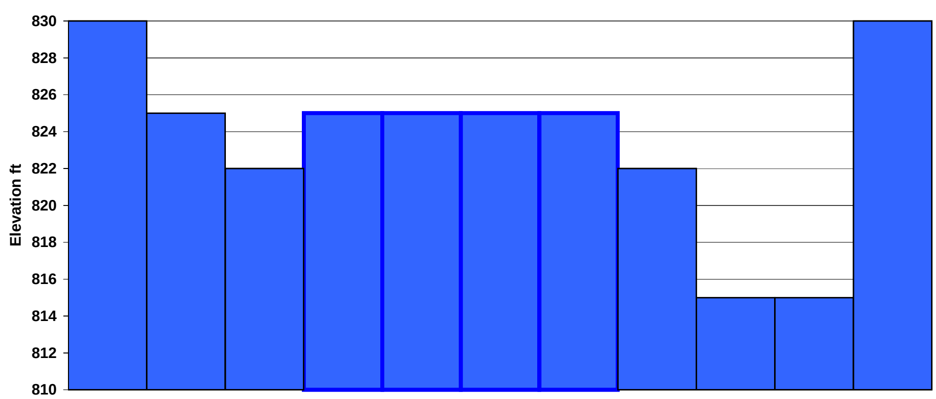
CONTRACTOR BENCHMARKS

Bypass River
Dewater Channel
Coffer Dam
Second Pump

Dewatering Depths / Day

Top of Weir

Water Level (ft.)



ARCHAEOLOGICAL TASKS:

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
1/12/2004	1/13/2004	1/14/2004	1/15/2004	1/16/2004	1/17/2004	1/18/2004	1/19/2004	1/20/2004	1/21/2004	1/22/2004

- ***Profile Trench-Channel at Weir***
- ***Exp. Channel Wall***
- ***Expose Dam - 5 ft.***
- ***Expose Dam - 8 ft.***
- **Demobilize -Snow**
- **Expose Dam - 16 ft.**
- **Prep Site for Recording**

GPS
- **Survey Foundry Wall**
- **Establish Datum Control**
- **Survey LIDAR Targets**

Rolleimetric Photogrammetry
3D LIDAR SCAN - 6 hrs

forced the rescheduling of the field effort and LIDAR recording for the following Monday, January 19th.

Temperatures did not exceed the low teens during the first week but rose to between 17 and 27 degrees Fahrenheit the following week. This created ideal conditions with clear skies and temperatures well within the operating limits of the LIDAR and other electronic systems.

The relative temperature fluctuations and potential for precipitation determined the final scheduling of the LIDAR recording tasks. As a light-emitting measuring system, LIDAR does not do well in rain or snow. The proposed recording needed a window of two days of clear skies and temperatures above its lowest operating tolerance of 14 degrees F.

By Sunday night, closely monitored weather reports suggested poor conditions for Monday, January 19th, but the prospect of clear skies and temperatures above 17 degrees for Tuesday and Wednesday, January 20th and 21st. This range was above the minimal tolerance level of the battery-powered LIDAR, but would be cold enough to maintain the site as a frozen and therefore stabilized matrix of otherwise muddy channel sediments (Table I). Accordingly, the archaeologist and contractor decided to continue clearing the site on Monday and to schedule GPS datum control as well as LIDAR mapping tasks for Tuesday and Wednesday, respectively.

The original plan to focus the field effort on one trench across the channel near the post-1927 cement weir was significantly expanded upon the unexpected discovery of the surviving eastern side of the original post-1830 cut-stone Furnace Falls dam on the first day of fieldwork. The surprising finding beneath a cap of more recent cement at the spillway brought about the need to excavate the channel in order to define its form, dimensions, depth and internal structure.

When not frozen, the waterlogged deposits within the river channel would have turned into a loose slurry while under construction, prone to mud slides and subsidence. Under normal conditions, any deep exposures within the channel would have required extensive areas of sheeting to stabilize and hold back the mud. After intense discussions and strategizing, the author, as the archaeologist, and Jeff Salmon of Salmon Brothers

Construction of Netcong/New Jersey, the contractor, decided to proceed with caution, keeping staff out of the excavation channel. They used the solidity of the frozen mud to probe to the base of the dam without shoring. The field strategy was also expanded to provide for a gentle slope within the excavated channel between the stone dam and a temporary earth coffer dam built 30 ft. to the east to block the flow of water through the weir into the channel.

It had been agreed that the New Jersey Division of Parks and Forestry – Hopatcong State Park would assist in the deep winter fieldwork by restricting the flow of water from upriver dams, to the east of Stanhope, until the end of the proposed LIDAR survey of the site. Despite severe weather conditions, the bypass pipes were able to convey the flow in the river and enable the Contractor to maintain a dry work area during the entire LIDAR survey process.

The Contractor had to first control and then sufficiently reduce the flow volume and water level of the Musconetcong River within the Furnace Falls channel to make the archaeology possible. Starting in November, Salmon Brothers constructed an innovative siphon-based river bypass system which was completed by the first week of January. A total of six passive 1-foot pipes were activated by the week of January 9th.

Tuesday, January 20th, was dedicated to the establishment of precise datum control points with high resolution satellite-linked GPS stations.

Wednesday, January 21st, was set aside for the documentation of the historic channel complex with the high resolution ground based LIDAR scanning system. Heavy-machinery clearing of the debris and fill continued until the moment of the scan. Despite the extreme weather conditions, all systems worked as planned. The new generation of true color LIDAR mapping systems produced a rapid and safe 3D geo-referenced record of the historic channel, dam and weir. The scanner produced a dense cloud of coordinate points tied to the NJ State Plane Coordinate system with a resolution of 6 mm per point; a point interval of 15 mm and a scan rate of 12,000 points per second (see Appendix III - Riegl specifications).

A final field task consisted of recording a measured cross section profile of the dam. Following final design changes, the contractor demolished and removed the remnants of more recent cement wing walls between January 21st and 29th to expose the southern end of the early cut-stone dam. The PI returned alone on the 29th and worked with heavy machinery (a 1.5 cu. ft. tracked backhoe and a heavy gauge pneumatic jack hammer) to expose and clean the dam for recording.

Discovering the Dam

At the outset of fieldwork, it was still not clear what, and if anything, the spillway could reveal. All visible surface elements of the spillway, the wing walls, the exposed top and the western, downriver, face of the Furnace Falls dam appeared to be of cement. No historic stonework or masonry suggesting an early construction date was visible.

However, several early maps and scaled historic map comparisons suggested caution. Two maps from 1828 and 1858, both predating the 1874 addition of the cut-stone bridge, showed a wide lake defined by a long, substantial looking dam structure at, or in alignment with, the modern spillway (Figures 2 & 3).

The survival of the historic dam underneath the cement cap was first discovered by Salmon Brothers Construction as an unexpected byproduct of the pre-fieldwork dewatering effort. Over the weekend before the archaeologists' arrival, the pumps and bypass pipes had lowered the water to a level 4 ft. below the lip of the spillway (Figures 17 & 18). While the top of the spillway continued to show a solid cement face, the rear, upriver, eastern side revealed the well-defined and tightly laid stonework of what emerged to be a section of the original pre-Civil War, 1830-40 era, dry-laid cut-stone dam built contemporarily with the Morris Canal.

This discovery by the contractor brought about a shift in field strategy. While the documentation of the cement spillway, prior to its removal before the opening of the channel, had from the beginning been part of the mandated Mitigation Plan, the new discovery added some field and analysis time to the overall effort. It proved inconsequential, however, to the speed and recording capabilities of the LIDAR. The site was documented in 3D with the same number and location of survey stations as had been proposed prior to the emergence of the early component of the dam.

Diverting and Dewatering the River

The discovery of the earlier stone dam raised logistical challenges, some problematic due to the weather, others aided by the deep winter conditions. The goal was to try to dewater the channel and remove enough of the sediments in front of the eastern face of the dam to establish and record its depth. It was decided to use the extreme weather conditions to our advantage. Instead of using expensive sheeting to stabilize the steep sides of the deepening channel excavation, the decision was made to use the freezing temperatures to solidify and stabilize the unsupported structures.

The process of deep exposure was done in two stages. During the first two days of fieldwork, Tuesday and Wednesday, January 13th and 14th (before the snow storm of January 15th), a single 6-inch pump made it possible to dredge and drain the eastern face of the dam down to between 5 and 8 ft. below it crest (Figures 20 & 21). But after good progress on Tuesday, January 13, Wednesday the 14th saw no advance in the depth of the exposure. After two days of clearing out mud with the backhoe and the full time use of a single 6-inch pump, it became clear that the water level was not going deeper than 8 ft. below the spillway lip and that the waterlogged slurry of channel deposits was slumping into the trenching area faster than the large 1.5 ft. backhoe could handle. Seepage of water through the shallow weir proved too great for the single pump.

The snow storm of Wednesday evening stopped work temporarily. However, it presented a critical opportunity for both contractor and archaeologist to address the upcoming deep winter and high water logistical challenges caused by the sub-freezing conditions.

The archaeologists used the time to equip themselves with additional deep winter gear, arctic boots and ice crampons. The frozen ground and channel sidings were precarious and slippery. The addition of ice crampons provided sure footing on the slick surfaces that had to be traversed to place scales and identification breadboards for each formal recording session.

The contractor used the break to develop a strategy to go deeper, and lower the water an additional 6 ft. to give the archaeologist access to the base of the dam. Salmon Brothers Construction built a temporary earthen coffer dam across the channel immediately west of the Quirk outfall drain pipe coming out of the southern bank, half way between the bridge and the dam, to cut off seepage from the weir (Figures 45 & 54). A second 6-inch pump was added to the existing 6-inch pump within the withholding pond formed by the coffer dam to control and then lower the water level in the upper channel and to block additional leakage into the deepening exposure from the cut-stone dam façade.

Downriver, the deepening hole in front of the dam was drained of any seepage through the coffer dam with an extra 3-inch pump. In addition, the exposure area was expanded and given a gradual (1:1) slope between the coffer dam at mid-channel and the cut-stone dam downstream as an alternative to sheeting. This grade was cut so as to meet health and safety mandates and to preclude the sudden implosion of the waterlogged deposits of mixed sediments and cement debris.

Later, as a final step to bring the water level to its maximum lower limit, the 3-inch pump installed at the bottom of the pit next to the dam drained the remaining water which had pooled in front of the dam immediately before the site was cleared of machinery and planking for the LIDAR scan.

Health and Safety Issues

Access to the east side and ends of the dam was limited by the potential instability of the overhanging early 20th century cement wing walls which cut across both ends of the exposed cut-stone dam. Their lower sections had collapsed or crumbled into large slabs of concrete in the channel, leaving their upper sections suspended as precarious overhanging wings of cement 10 – 15 ft. over the empty cavity below (Figures 21, 24 & 51). For this reason, any and all human activity in the pit was restricted in the vicinity of the unsupported wing walls remnants. Only a thin sliver of access was defined in a line perpendicular to the central portion of the dam’s eastern face.

Access for the archaeologists and later for the LIDAR team to the face of the dam was provided by large multi-beam wooden “tank” mats. These were hoisted by crane over the jagged surface of the frozen channel to form a bridge to the face of the dam (Figures 12 & 20). These walkways permitted the archaeologists to safely get close enough to the dam to briefly inspect its façade and to place scales and photographic breadboards on the structure.

Pre-LIDAR Site Preparations

The final dewatering and maximal exposure of the eastern face of the cut-stone dam beneath the spillway took until the morning of the last day of fieldwork. The 1.5 cu. ft. backhoe bucket, the crane-mounted crushing ball, the crane-mounted clam shell and pumped water were also used intensively to break apart and remove large chunks of the collapsed cement wing wall. They were also instrumental in removing debris which clogged both the excavation trench and the unexposed northern end of the dam at its juncture with the recent sheeting. This sheeting had been installed on an emergency basis after the severe flooding of 2000.

The first half of the one-day LIDAR-recording effort was dedicated to cleaning off the snow and ice that blanketed the site. The dam and southern retaining wall of the historic channel were flushed with water from the 3- and 8-inch dewatering pumps and with large backhoe and crane buckets of water from the channel. A cap of 3 inches of ice was chipped and smashed with the backhoe and then cleared away with the help of pump outfall hoses tied to the bucket of the small backhoe which directed and pointed the 6-inch flow from one of the dewatering pumps.

The morning of the LIDAR scan was also taken up with making the site safe for the LIDAR team. The first two survey stations were set up on the roof of the post-1901 Singer building to provide coverage of the western cement face of the spillway while clearing and dewatering operations continued upstream. Throughout the morning, the contractor and personnel from Compac Corporation worked to make the ice-covered roof safe for the technicians and equipment. As a final task before the midday start of the

LIDAR scanning, vehicles, tank mats and construction equipment were shifted off-site to provide a clear field of view for the scanner.

Profiling the Channel

The original Mitigation Plan (Grossman, 2002) recommended a single-profile trench across the historic channel to define its depth and structural characterization. Based on Vermeule's plans, it was initially assumed that the cement weir would be some 5 - 6 ft. deep and formed with a sloping or expanding cement base that flared to a wide cement base. The north-south trench was to be placed next to the post-1927 weir so as to us it for support or, better, as an already existing safety wall. Assuming a ca 5 – 6 ft. depth range, a 10 ft. wide channel would be necessary to provide for a gradually sloping side stepped back with a 1:1 slope to avoid the need for costly, and potentially impacting, steel sheeting within the channel. The trenching across the channel was begun on Tuesday, January 14. It was completed on schedule and the site was prepared for recording by the morning of the last day, Wednesday, January 21.

The progress of the clearing was slowed by the rapid buildup of suspended sediment in the water and by a spurt inflow into the channel. A second 6-inch pump was added and together, the two pumps they were able to match, and even surpass, the flow through the weir. The lowest water level reached through dewatering stayed at around 5.5 ft., or elevation 824.5 ft., below the top of the weir (at 830 ft. El). Attempts to further stem the flow of seepage from the Furnace Pond or increase the rate of pumping proved futile. However, the successful dewatering of the channel to this depth provided enough exposure to define the depth of the channel and the bottom of each wall, or channel section, in the vicinity of the weir and the former cut- stone bridge abutment (Figures 33 & 34).

On the morning of Wednesday, January 21, the turbidity in the channel from the previous day's dredging had cleared sufficiently to reveal that the base of each wall was demarcated by the presence of wooden log footers under the last course of stonework.

Wooden footers had been reported by Brian Morrell from excavations of the Morris Canal in Warren County, and it was projected that the base of the channel would be defined by wood in this case as well (Morrell 1983).

Each “footer” or “spreader” was laid east-west and parallel to the axis of the channel. Both logs were smooth and relatively thin, ca. 5 - 7 inches in thickness, and appeared to be smooth, rounded trimmed branches or thin trunks stripped or of bark. No saw or chisel marks were visible to the eyes, on film, or through the 22 power digital video lens (Figures 35 & 36, see Disk I-Digital Video Field Log).

Both could only be recorded while they were partially submerged in the constant flow of water covering the bottom of the channel. On both sides, the eastern-most end of each log, located close to the weir, was partially exposed on its uppermost side, but was covered by water towards its western, downriver, end. Both logs were recorded in and under water with digital camera and digital video and as well as in multiple Rolleimetric flat field macro views (Appendix II Index of Rolleimetric Images and Disk I for digital image files.

As recorded on the 3D LIDAR view (Figure 53, NPI Plan 3/6-Section C), the bottom of the cut-stone channel and wing wall was at El 824.5 foot. The top of each wall ranged from elevation 832 ft. on the southern wing to 834+ ft. on the northern wing wall. The depth and/or height of each channel wall in the vicinity of the former bridge abutment varied between 7.5 ft. for the southern channel wall and 9.5 - 10 ft. for the northern wall. Both walls were constructed of the same dry-laid stonework of rectangular blocks of gray metamorphic stone, ranging from ca. 1 to 2 ft. in vertical thickness and 3.5 to 4 ft. in length (Figures 41 & 42).

The profile trench across the channel brought two unexpected results. The first was the discovery that the post-1927 weir was only a shallow, near-surface structure with no actual base or wall to the bottom of the channel. The second was that the channel entrance, or easternmost channel opening and its associated cut-stone wing walls, had been preserved under modern debris and ground cover.

Defining the Weir

When excavated and exposed through dewatering, the actual weir structure turned out to be very different from that outlined in Vermeule's Canal closing plans (Vermeule 1929). Vermeule's 1927 blueprints had illustrated the proposed weir in several measured section drawings as an expanding, poured vertical cement slab with a horizontal cement footer expanding outward at its base (Figures 41 & 42). Vermeule's original blueprints did not specify depth (Grossman 2002, Figure 34, *Drawing No. 263A, NJ State Archives, Box 37, item Number 1, "Plans for work on Section 54-55")*. Notations on the drawings stipulated only that the depth of the base of the weir "El (Elevation) was to be determined in the field" (Figure 42).

The archaeological definitions and measurements of the weir recorded in January 2004 showed elements similar to Vermeule's 1927 blueprints depictions (Figures 2, 41 & 42). The top of the cement slab and its three cement "pods" with vertical beam slots were present but the weir did not match Vermeule's drawings for their underlying form and dimensions. Vermeule's Canal closing blueprints showed profiles for a vertical cement weir with a flaring cast base, like an integrated footer or spreader, extending to the base of the channel. None was present (Figure 42). The eroded base of the cement weir rested on loose gravel 3.9 ft. above the recorded bottom of the channel (encountered at a depth of 5.5 ft. below the weir, elevation 824.5 feet). Instead of extending to the bottom of the channel, the cement weir had no base and no connection to the bottom of the channel. In essence, if Vermeule's blueprint did pertain to the weir at Furnace Falls, it was not built to his specifications.

The exposure process revealed that the weir had been constructed only as a near-surface, cast rectangular cement slab without a base extending to the bottom of the channel. The slab measured 2.8 ft. by 1.9 ft. thick in section and 25.8 ft. in length (NPI Plan 3/6-Section C). The northern half of the bottom of the cement weir was heavily eroded. It had been reduced by 25 to 50 % of its original thickness at its northern end, and appears to have measured at least 2.5 to 3 ft. thick when originally built (Figure 34).

The weir appeared to be self-standing and was not built into, or structurally integrated with, the earlier cut-stone wing walls. Instead, it appears to have been poured in a form over an unconsolidated matrix of gravel and jagged furnace-derived slag that filled the channel and dominated in the dry fill along both banks of the channel.

The north end of the weir had been apparently been poured over, or onto, a large irregular boulder, ca. 18 inches in diameter, resting next to, but independently from, the northern cut-stone channel wall. The boulder appears to have subsequently broken away from the cement weir and subsided to form a large cavity immediately next to the cut-stone wing wall (Figures 33 & 35). The actual elevation of the weir varied from north to south by 3/10 ft., between 830.1 and 829.8 ft., reflecting probable subsidence into the porous gravel bedding beneath it (NPI-Plan 3/6-Section C; Plan 2/6-Section A).

Three cement pods extended upwards from the top surface of the horizontal cement slab, each with vertical board slots on either side (east and west). The cement pods measured 3.1 ft. high and 2.2 ft. wide on their east-west axis. The addition of horizontal planks into the slots thus gave the potential to raise the water level at the weir up to 3 ft., between 830 and 833 ft. elevation, above the top of the horizontal cement slab of the weir.

The weir and eastern channel were “sectioned” and recorded in plan, profile and 3D by LIDAR and with digital cameras, digital video and Rolleimetric photography (NPI-Plan 2/6-Section A; Plan 3/6-Section C; Figure 53).

<u>The Surviving Bridge Abutment Wing Walls</u>

The archaeological profile trench across the channel at the weir also exposed the intact eastern opening, or 19th century wing walls, of the original 1874 cut-stone bridge abutment. The outer edges of both wing walls were difficult to define during the LIDAR scan because of the amount of snow and debris on the lake side of the weir. The full extent of the wing walls had been plotted in detail in the 1979 Secco survey of the Compac Corporation property, but was not exposed during the more recent surveys after the 2000 floods (Secco, 1979). They were not depicted on the official engineering survey plans (Figure 10).

However, between January 21st and 29th, clearing in preparation for the installation of sheeting revealed a ca. 10 ft. section of the northern wing wall which defined both the interior southern edge of the wall as well as the outside edge of the northern wing wall. In addition to the LIDAR scans, both digital and film-based photography were used to capture this section. Details were documented by Rolleimetric flat field film records (Appendix II).

The northern wing wall measured 2.5 ft. in width (Figure 35 & 53). Although not exposed equally on both sides of the channel, it is reasonable to assume that the southern wing wall had this dimension as well. The photo image suggests that both sides of each wing wall had been constructed as self-supporting double faced, dry laid, stone walls (Figure 35).

The cement weir was cast outside and to the east of the main channel formed by the bridge abutment. It was positioned to fit as a plug in the mouth of the expanding funnel-shaped wing walls, facing Furnace Pond, with little or no integration apparent with the cut-stone channel siding on either side. The channel measured 19.9 ft. in width. The cast cement weir was measured 25.9 ft. at its widest. It was placed 2.5 ft. east of the juncture, or vertex, of the channel with the expanding cut-stone wing walls to the east.

The wing walls flared at an angle of 22 degrees on the north side and 24 degrees on the south side of the weir. They extended eastward for an absolute distance of 7.3 ft. in line with the channel wall and 8.1 ft. beyond the eastern side of the weir in line with the wing wall (NPI-Plan 3/6-Section C; Figures 39, 40 & 53). In shape and orientation, the two wing walls look very similar to the inlet of the Lock 1 West of the Morris Canal currently preserved adjacent to Lake Musconetcong in Stanhope.

Project engineers and contractors have reported that the current construction plans will maintain the cut-stone wing walls in place throughout the construction and in essence incorporate them into the specifications for the channel and dam remediation. Langan Engineering and Salmon Brothers Construction specified that the …"…abutment will be left in place and incorporated into the channel design." (Personal Communication via email: D.J., Hodson, February 26, 2004). The new channel lining will grade into, and rest against, but not otherwise impact the historic wing wall structures.

The Southern Channel Embankment

The southern bank of the channel, located between the weir and the spillway to the west, contained three different levels of preservation and categories of stonework: The area of the weir and the former bridge abutment, a 60 ft. long disturbed central section between the weir and the spillway, and, at the western end, a 30 ft. undisturbed horizontal band of dry-laid boulders adjacent to the curving southern cement wing wall of the spillway (Figure 54).

Consequently, three profiles were recorded with the LIDAR to document the structural variation of the channel's exposed southern embankment (NPI Plan 1/6 Section C, Plan 2/6-Section B, Plan 5/6 Section E).

The eastern-most profile nearest to the weir (NPI Plan-1/Section C) documented the surviving lower elements of the bridge abutment. Double flaring wing walls were present on either side of the center line of the bridge's former north-south alignment. The base of the surviving bridge abutment was distinguished by a line of large, 6.5 ft. deep, stone blocks of the former 1874 arched bridge. These surviving wall elements ranged in elevation from 825.5 ft. to 832 feet (NPI-Plan 2/6-Section B, Figure 54).

The center section of the south bank of the channel was disturbed by modern, probably post-1960, intrusions associated with the installation of a 24-inch storm sewer or conduit outfall pipe draining into the central channel from Quirk Corporation. Next to the pipe was a flat-topped cement slab over a cement box of undetermined function (Figures 10 & 54).

The third and westernmost subdivision of the embankment consisted of an undisturbed, 30 ft. long, line of un-mortared cut-stone blocks or, better, what appeared as rough cut boulders with rounded edges. In contrast to the depth of the bridge abutment, this western section consisted of only a 4.5 ft. high, three courses thick, band of cut-stone blocks between 828.5 ft. and 833 ft. in elevation. Throughout its length, no stonework was encountered below elevation 828.5 feet. This section began due west of the cement box and extended to the eastern end of the flaring cement wing wall bounding the lower spillway. A LIDAR profile across the vertical axis of this surviving section of embankment recorded the top and bottom elevations of the upper and lower coursing (See NPI Plan 5/6-Section E).

Its relative height when compared to the elevation of the weir at 830+ ft. indicates that this multi-course band of cut-stone began one course below the crest of the weir. This elevation range suggests that it may not have been installed until after the post-1927 cement weir had raised the flow levels in the channel to 830+ ft., or to between 830 and 833 with boards slotted into the weir pods (Figure 51, NPI Plan 2/6 – Section B, Plan 3/6 – Section C, Plan 5/6 - Section E).

Their position in the channel may have more to do with, and date to, the era of Vermeule's canal closing operations and the realignment of the channel spillway, co-terminus with the installation of the cement wing walls on the spillway, than the earlier 1874 cut-stone bridge and stone wing wall construction at the eastern end of the channel.

<u>The 1830 Stone Dam at Furnace Falls</u>

The excavation of the stone dam at Furnace Falls revealed that it was a multi-component structure consisting of elements of both the earliest period of construction at the site and the later cement additions, which probably dated to sometime within the first quarter of the 20th century.

The earlier, dry-laid cut-stone, component was visible only on the eastern face of the spillway and appears to date to the early to mid-19th century. The western face was removed at some later date, and replaced with at least two, and possibly three, episodes of added cement reinforcement, or cladding. No independent evidence (inscriptions, makers' marks or associated dateable artifacts) was recovered to set the date of these changes or additions. Only their relative composition, construction materials and elevations, which link the dam to other structural elements at the site, offer potential clues as to their relative contemporaniety (See Discussion).

The dewatering and excavation process exposed enough of the dam's face to indicate that it was built as a truncated, or flat-topped, stepped pyramid form with a 1.1 ft. wide step, or shelf, at a depth of ca. 6 ft. (5.9 ft.) below the lip of the spillway (Figure 51-52, NPI Plan 5/6-Section F). This step extended across the eastern face of the cut-stone dam and had been truncated and cut into by the later cement wing wall construction on either side. The horizontal position of one stone block in the disturbed north end of the dam (Figure 32) suggested that this step, or shelf, may have extended north and south across the path of the later wing wall builders' trench. The level of disturbance from the later cement wing wall construction, however, left its original extent and form indefinable.

No exposure was done to the north or south of either of the cement wing walls of the spillway. The 1828 and 1858 maps of Furnace Falls both, however, suggest that the original dam appears to have extended to the north and south of the most recent spillway by a considerable distance (Figures 2 & 3). The relative scale of the dam's length suggests that it may have originally extended as much as some 200 ft. across the basin to tie into high ground, bordering the Musconetcong River (Grossman 2002).

The archaeological exposure of the earliest surviving cut-stone has revealed salient new insights into the structure, size, construction and chronology of the dam. This is a summary:

The cut-stone portion of the dam was characterized by structurally and stylistically distanced elements or attributes: (1) Its form and depth, and (2) the presence of finished corners suggesting that there had been at least one former lower sluiceway.

(1**) Form and Dimensions:** In total, the dam measured a minimum of 15-16 ft. from top to bottom, 7.4 ft. across the east-west axis at its crest, and 11.1 ft.. wide at its base (NPI Plan 5/6-Section F). The exterior cement face of the dam added later was shorter than the exposed interior cut-stone face. It sloped outwards to join the cement channel floor at elevation 819.4, or 10.6 ft. below its crest, at least three 3 to 4 ft. less in height than the opposite, upriver side of the structure. The cement-capped top of the dam was at elevation 830 ft., and its base extended down to 814 - 815 ft. elevation on its eastern face.

The LIDAR scan was able to capture only as far down as the water which stood at 816.5 ft., several ft. above the actual depth of the stone dam. The level of water measured against the ca. 5 ft. high, 1.5 cubic yard backhoe bucket suggested that the base extended at least 1 – 2 ft. below the standing water pooled at its base, or at least to between 15 and 16 ft. below the lip (to elevation 814 - 815 ft.) at its deepest invert in the channel.

The potential for collapse and/or subsidence from undercutting too much mandated that the northern and southern slopes of the exposure be left unexplored. Only the central point of the eastern face could be exposed to this depth.

During the LIDAR survey, the top of the stone dam was capped by a 3–5 inch thick layer of cement, which in turn was covered by eight 8 inches of snow and ice. This cover of cement, snow and ice added about a foot to the height of the original dam.
It also added an artificial extension, or eve, to the top eastern corner. This frozen overhang gave a false profile signature to the LIDAR scanner at the top eastern edge. As recorded in NPI profile Section "F", and as captured in the Rolleimetric flat-field macro image, the original edge formed a clean 90 degree juncture at its vertical eastern edge (Figures 31 & 32).

(2) **Finished Corners**: The excavation and dewatering process exposed the well-preserved, square north-east corner of the original cut-stone dam structure. The presence of this clearly defined corner, directly in line with the south side of the northern wing wall of the Singer spillway, suggests that what later became the base of the most recent cement-covered spillway may have been the upper ledge of a previously existing lower channel outlet, or sluiceway, where the later northern wing wall had been constructed. The notion that the dam had a lower sluiceway immediately to the north also correlates with the "pre-construction" blueprint of the spillway as depicted in Vermeule's 1927 Canal closing engineering plans (Figure 41). It also fits with the earlier 1828 map showing double spillways out of the dam as it appeared before the construction of the post-1874 cut-stone arched bridge (Figure 2).

Profiling the Dam

Exposure

The DEP-mandated procedure of profiling or sectioning the dam before it was demolished presented logistical and scheduling challenges. Feedback by review staff regarding the initial fieldwork results had focused on the need of recovering controlled information on the interior structure and construction of the dam. In response, the archaeologist and contractor had evaluated several possible ways to achieve this end safely and without interrupting the ongoing construction. At first, the possibility of using a line of drill holes to cut the dam in half was considered. This would have been costly and time-consuming. It was, instead, decided to phase the archaeological procedure (cut, clean, record) into the upcoming demolition phase.

The final task, the sectioning of the dam to record a profile cross-section of its internal structure, was undertaken on Friday, January 29th, 2004.

In the intervening week since the LIDAR scan of January 21st, the contractor had removed or jack-hammered 16 -17 ft. of the former cement spillway wing walls off the pre-construction 2003 surface height of 836.5 ft. elevation, down to the surviving base of the vertical cement sidings at ca. 820 ft. elevation. The removal of the wing walls provided access to the southern edge of the dam and a means to record it in section. The opposite, northern end was inaccessible because of the density of sheeting that had been installed after the flood damage of 2000.

Once the exposed stone work had been accessed, definition, documentation and demolition steps were treated as archaeological procedures under the direct supervision of Dr. Grossman.

The day was divided into four segments based on the need to slot the photography and photogrammetry to optimum sunlight conditions (10 AM – 1 PM).

Between 9 and 11:30 AM, the Salmon Brothers team deployed a heavy-tracked backhoe and pneumatic jack-hammer to cut away the remaining wing wall and to cut a clean cross section profile through it in line with the exposed south face of the structure.

By 11:30 AM, tasks shifted to cleaning and preparation for photography and photogrammetry. Two construction workers with heavy brooms were raised onto the exposed column of the structure. They cleared snow and ice from the top surface and swept loose dirt and rubble off the top and sides of the frozen matrix. Earlier and warmer conditions had permitted the use of water to clean off the exposed eastern side of the dam. However, this day the temperatures had dropped into the teens, and it was judged to be too cold to use water to clean without the prospect of turning the feature into a dirty ice-covered mass.

The third stage was the photographic documentation, the forth comprised the demolition and recording of the dam’s upper section with digital video by 2:30 PM.

Photographic, Digital and Metric Documentation

Digital camera, digital video and Rolleimetric photography were used to document the internal structure of the dam. Each of these systems was used at slightly different times over the hour between 1 and 2 PM, and each captured slightly different kinds of visual information. Neither hands-on inspection nor the recordings of detailed measurements were possible because of dangers posed by rising waters and slumping banks surrounding the structure. A 22 X zoom DV camera was used instead, from a safe distance of 60 to 75 ft. away from high ground to the south. The remote zoom recording technique provided an opportunity to perform a detailed “close-up” vertical and horizontal inspection of the exposed façade, with the same clarity as if one was inspecting it from a distance of 2 - 3 feet.

Consistent with the DEP guidelines for the submission of digital media, the DV record of the dam is included as an integral part of the report within the appended “DV Field Log” of the excavation entitled *GPS and LIDAR in the Discovery and Documentation of Furnace Falls Dam, Channel and Weir* (Grossman-Disk 1). This digital video record provides a context for the multi-medial DV close-up survey record of the dam profile. It also presents close-up and otherwise inaccessible details of the wooden footers under the cut-stone abutment and wing walls near the weir, and the LIDAR-derived 3D animations and virtual inspections around and over the excavation.

The final phase of the data documentation task was marked by the need to provide safe physical access to the structure and control the rising water long enough for the PI to take flawlessly vertical metric file photographs of the south end of the sectioned dam with the Rolleimetric camera. This proved to pose a challenge.

The contractor had built a berm and equipment access routes for the archaeologists and heavy machinery across the channel and around the dam. However, at the moment of photography at mid-day, water levels had begun to rise and breach through the berm. So that the PI could take the shots perpendicular to the mid-point of the dam, the water had to be at least temporarily controlled and an access terrace or step cut into the surrounding berm.

The digital photographs taken minutes before had documented the dam's face to a depth of 8 ft. below its crest, or to elevation 822 feet. To provide maximal coverage for the Rolleimetric photos, the PI directed the heavy equipment to couple the cutting of the lower step with the simultaneous removal of the rising waters with the 1.5 cubic yard backhoe. The shelf cut, the author dropped flat onto it, and the backhoe repeatedly scooped out water to lower it an additional 2 ft. immediately before the shot was taken. This effort increased the vertical exposure down to a maximum lowering of 11 ft. (elevation 819 ft.) below the top of the spillway at 830 feet. (Figure 32).

Aside from an unavoidable dark shadow from the brightness and angle of the sun, the automatic wide angle (90 degree) lens of the Rolleimetric and the low light, high speed (800 ASA), high resolution *Fujicolor* film captured a detailed and vivid as well as accurate color record of the exposed face of the dam. The film-based Rolleimetric provided better color accuracy than the digital photography (Figures 29 & 30), which proved adept at capturing detail but had limitations in the color accuracy of red and earth color materials (Figure 31).

All dimension and elevation measurements were derived from the LIDAR after the end of fieldwork. The total site LIDAR survey of January 21st had recorded the exposed historic structures in a series of dense "point clouds" of millions of geo-referenced 6 mm, precise 3D coordinates. Out of the field, the author selected an area to cross-section in virtual space, and through the LIDAR software, *Polyworks* and *RiScan*, extracted a mm-precise profile drawing across the top and both sides of the dam to its base, demarcated in feet and tenths of feet in actual elevation units. The outside dimensions and elevation of corners and surfaces were defined exclusively by the LIDAR (NPI Plan 5/6 - Section F).

The image records and macro digital profile images were correlated and graphically integrated with the measured technical drawings derived from the geo-referenced coordinate-linked 3D LIDAR scan profiles. The 120 mm Rolleimetric film was scanned at a photo laboratory into a 50 Mb digital file and then adjusted with image processing software to balance light and contrast levels. The digitized film scan was then reduced in size and image resolution from 300 dpi to 72dpi for dissemination as part of the formal report (See Appendix II of Index Contact Sheets and Disk I for actual files).

The "core" outline of the dam profile was digitally "cut out" from the scanned Rolleimetric background image (Figure 31) and then imported as a layer and scaled to the LIDAR-derived profile (NPI – Plan 5/6 - Section F). to yield a measured profile drawing of the internal structure of the dam (Figure 32). This may have been the first time that LIDAR coordinate data were integrated with high resolution photogrammetry to create a measured archaeological profile (Figure 32).

Internal Structure

In profile, the interior matrix of the dam had a smooth, slightly sloping vertical cut line parallel to the poured western, or downriver, faces of the spillway (Figure 32).

At the top of the western, or downriver, side, this cement cladding measured 1.5 ft. thick. At 1.5 ft. below the western corner, the cement flared outward to form a thicker lower portion, 9.5 ft. high and 4.5 ft. thick at its base.

The smooth flat interface of the cement cladding with the core of the earlier cut-stone dam suggested that, if formally present, the earlier outer face of cut-stone had been removed and replaced with cement poured in a form on at least one or possibly two occasions. This replacement permits the conclusion that it may have been close to the same width, or east west, thickness as the original structure, or around 7 ft. across its top and 11 or 12 ft. across at its base.

A central seam of loose soil and rubble between the eastern cut-stone face and the later western cement surfacing had initially suggested the unlikely possibility that the dam had been built as a stone-faced but rubble-filled structure. However, the straight line of the inner cement seam alternatively suggests that it was poured with a frame or mold and that the loose material in the center in all probability represents fill or earth "packing" behind the cement framing. It is more likely that the apparent fill and rubble wedged between the cement and the eastern cut-stone face was placed there only after the western cut-stone face had been rebuilt, sometime in the first quarter of the 20th century.

The cement exterior cladding appears to have been added in at least two, possibly three, separate pours. This is indicated by least three different types of cement matrix visible in the digital and photographic record (Figures 29 & 30).

The first indication, as recorded by the LIDAR scan and by the digital video and photography, is that the outside face had a horizontal seam line at 5.9 ft. below the crest (el 824+), at the same elevation as, and parallel to, the eastern stone step on the opposite façade (Figures 48 & 49, NPI Plan 5/6 - Section F).

The second indication is that cutting the southern wing wall with the heavy-track jack hammer to form a clean profile section showed that there were at least two different types of cement within the interior of the outer façade of the spillway. The upper half, or upper 7 ft., of the exterior cement cladding consisted of homogenous, fine-grained cement and gravel concrete of a uniform color and consistency. Below the elevation of 823 ft., and extending down to its juncture with the cement floor of the channel leading under the Singer building, the concrete showed dense inclusions of brick fragments, or "brickbats", in the matrix (Figure 29).

The digital photos also showed a distinct outer vertical band of concrete with a finer matrix which was devoid of brick fragments. This outer layer appears to have been added as a third cladding to the western façade of the rehabilitated Furnace Falls dam, and later spillway.

Using the large backhoe, the upper course of the dam structure was sectioned in a series of parallel vertical slices from south to north. This approach was to document any lateral variations in internal construction of the dam which might be different from what had been recorded along the south end. There were no differences. The surviving eastern face of the cut-stone structure showed the same interior structure throughout its length.

The demolition of the dam was planned and directed in stages as an archaeological procedure. It was also recorded and monitored with digital photography and digital video. These records are submitted as part of the DV Field Log of the data recovery procedures (Disk I).

Discussion

Historic Hydrology

The archaeological investigation documented significant new information on the structure and history of Furnace Falls dam, channel and later cement weir. The combined map and archaeological evidence suggests two projections:

(1) The finished cut-stone corner represents the southern edge of a former 19th century spillway or sluiceway that was some five to six feet lower than and immediately to the north of the recent cement spillway, and

(2) At least the northern side of the later cement wing walls, and possibly both, appear to have been built into a former sluiceway.

This projection in turn suggests that the original 1840 pond was both much larger than the most recent one and that its shoreline was at elevation 824 to 825 ft, some 6 ft. lower than that formed after the 20th century addition of the weir and the raising of the cement spillway to elevation 830 feet.

The surviving cut-stone portion of the original structure appears to coincide in location and alignment with the earliest 1828 and 1858 maps of Furnace Pond (Figures 2 & 3). The photographs of the cut-stone bridge lower spillway (Figures 6 & 7), provided courtesy of the Musconetcong Foundrymen Historical Society, can now be re-evaluated in light of the new archaeological evidence provided by the elevation of the previously unknown stone step at ca 6 ft. below the top of the dam and by the discovery of the smooth finished northeast corner.

Scaled Historic Photographic Evidence

Both historic photographs appear to be contemporary and possibly taken on the same day by the same person. Both show the same elevated rail berm above the top of the bridge's arch. The historic photograph of the bridge post-dates 1896 (based on the 1896 Rogers No. 352 Locomotive in the historic photo of the cut-stone bridge and lower spillways, Hollingsworth 1984). When scaled, the presumably contemporary photograph of the spillway suggests that it was formerly much lower than the most recent cement version (Figures 6 & 7). When the height of the spillway is compared to its ca. 20 ft. width, it appears that the earlier stone spillway was at least 5 ft. lower, or only some 6 ft. high, versus 11 ft. for the recently removed cement spillway.

If correct, these two lines of evidence together suggest that the original Furnace Falls dam had at least one spillway located immediately north of the current one and that its crest was at least 5 - 6 ft. lower than the 830 ft. elevation of the most recent spillway, or at approximately elevation 824 feet.

The photo also suggests that the horizontal location of the channel outlet, or sluiceway, appears to have been realigned between the time of the photo and the building of the cement spillway. This shift, combined with the evidence of the finished corner down to the level of the step, suggests in turn that the original dam had a sluiceway at ca 824- 825 ft. in elevation and that it was located with its southern end in line with the northern former cement wing wall and that it extended 20 ft. to the north of recent cement spillway. This archaeological and structural evidence in turn suggests that the 19th century water level of Furnace Pond was most probably at the 825 ft. contour levels as well. This projection is also close to the recorded depth of the bridge and channel stonework at the eastern end of the channel. The recent waterline at 830 ft. may not have been established until after the installation of the cement weir by Vermeule's Canal closing transformations after 1927 (Vermeule 1929).

Chronological Indicators

With the exception of a single note on Vermeule's 1927 plans for a spillway and weir in the vicinity, no documentary evidence has been recovered to establish the age of these two components of the reconstructed dam-spillway complex.

Two lines of evidence, cartographic and structural, suggest, especially given the lack of REBAR reinforcing, that the cement cladding of the lower spillway may be earlier than thought and in fact date to as early as the turn of the 20th century, or around the 1901 construction of the Singer Building across the Musconetcong River. Based on period engineering literature on the history and use of concrete in general, and hydraulic concrete in particular, it may be surmised that at least some of these additions are significantly older and go back to the 1901 date of the Singer building.

American and European engineers and chemists were actively writing about and implementing the use of hydraulic concrete by the decade of the 1870s, or co-terminous with the end of the American Civil War. Between 1869 and 1873, the maturation of this technology was underscored by the appearance of three major scientific and engineering works of the uses of hydraulic concrete in maritime and marine contexts. These were the "Practical Treatise on Coignet Beton and other Artificial Stone" by Major General Q.A. Gilmore, 1871, "Report of the Hydraulic Lime of Teil" by Leonard F. Beckwith, C.E., 1873, and "Treatise on Concrete" by Henry Reid, 1869 (see Ripley and Dana, 1873, Vol. V, 210 – 211).

As early as the 1830's, French maritime and structural engineers had successfully calculated the mass of cement necessary to withstand even the strongest ocean tides and wave action for the reconstruction of the dilapidated port of Algiers. They determined by experiment that, to be "immovable in the waves," cement blocks had to be "at least 353 cubic feet in size." By 1873, concrete blocks were also used in New York harbor to build and expand the post-Civil Battery at the tip of Lower Manhattan (Ripley and Dana, 1873, Vol. V, 211).

These precedents suggest that the solid cast cement wing walls at Furnace Falls may have been built any time after 1870. However, as discussed below, given the structural integration of the spillway wing walls with the cement façade of the dam, and the note on Vermeule's 1927 plans to "Remove and replace with Concrete Spillway" (Figure 41), it seems reasonable to project that at least some elements of the cement wing walls and facing were put in place in the late 1920's.

The Original Channel Alignment

Furthermore, the discovery that the original cut-stone dam had finished corners in the stonework, adjacent to and cut into by the builders trench of the later cast wing walls, suggests that the original spillway orientation and configuration was different from the 20th century one.

These differences in the location and alignment of the spillway in turn suggest that the later cement additions were added for the primary purpose of redirecting the channel of the Musconetcong into a realigned cement-lined channel beneath the Singer building. The new facing and wing walls were built not only to reinforce what was there but also to redirect the flow of the river into a realigned cement channel. If this is indeed the case, then it is reasonable to place the date of construction for the cement wing walls to as early as 1901, co-terminus with the building of the Singer Building and a cement-lined channel under the building.

It is also possible that the cement spillway and realigned channel were rehabilitated in several stages between 1901 and 1927. This suggestion is based on the observation that the cement wing walls appear to represent multiple phases of construction. The uniformity and parallelism in color and composition of the large, evenly-spaced, upper cement block-like steps bordering the channel west of the spillway contrast in composition and color with the lower sections of the wing walls extending east of, or upriver from, the spillway/dam. The curved, or flaring, upriver extensions to the wing walls and the presence of parallel horizontal mold or cast seams (Figure 50) suggest that these had been constructed by different techniques and possibly at different times.

Historic Topography

The new coordinate and elevation data now locks formerly ill-defined elements of the historic matrix into 3D space. This added information also suggests correlations and inter-relationships that were not previously possible to address. In addition to serving as essential benchmarks for the geo-referenced air photos of the areas, the new measurements of the top and bottom elevations of the cut-stone retaining wall now lets us extend correlations between this structure and other features on the site.

Precise elevation measurements at the top and bottom of the retaining wall in four locations now permit comparisons between it and the topography behind and above it within the access road corridor.

Topographic Correlations

The original 2002 background sensitivity study had suggested that the historic fill behind the massive cut-stone retaining wall contained a honeycomb of buried surfaces and conduits for air and water to power the blast furnaces of the foundry below (Grossman 2002).

This suggestion has been augmented by the newly available elevation measurements of the site's topography and primary historic features. The base of the wall, now partially covered by cement pavement of the modern Compac Corporation facility, consistently measured at elevation 820.2 to 820.3 feet. Equally consistent, the top of the wall measured between 834.5 and 836 in elevation and the original wall between 14 and 16 ft. in height throughout its length. These measurements, in turn, suggest that the original historic surface beneath the access road was also set to be at around 836 ft. in elevation when first filled in.

In contrast, the survey and excavation work of the Phase I access road mitigation had established the presence of buried historic features at around 845 ft. elevation. In neither exposure was the base or original surface these were built on, or into, identified.

The presence of a buried layer of the coal dust bordering the chimney base of Feature 3, at a foot below the modern access road, and the upper portion of a builder's trench associated with the mortared stone foundation of Feature 2, suggest these features were built on, or associated with, a buried late 19th century surface 2 and 5 ft. below the modern grade. In other words, these relatively recent foundry related structures, most probably associated with the turn of the century era operations of Musconetcong Iron Works, were in turn associated with the buried surface several feet below the modern one.

The new information, provided by the precise elevations surveyed for the top of the historic 1840 retaining wall of the original foundry, now suggest the presence of at least one and possibly more, and deeper, historic surfaces at the site, beginning at or around elevation 834 and 835 feet. This is at least 9 - 10 ft. below the level of the modern grade and some 4 to 5 ft. lower than the late 19th century surface of the excavated features (Feature 2 & 3, See End of Field Letter-Appendix I) in the access road documented in October of 2003.

This new evidence also permits the horizontal linkage of the formerly ill-defined and free-floating retaining wall with the scaled historic photographic evidence on the original height and topography of the post-1874 cut-stone arched bridge at the site.

As illustrated in Figure 5, the post-1896 photograph of the cut-stone bridge documents a later phase of land fill over the original surface elevation of the bridge. A 10 ft. high berm formed an elevated platform on top of the bridge in support of the late 19th to early 20th century rail lines into the site. Based on the scaled projection of LIDAR-measured bridge elements, and its original width and height as documented in the post-1896 photo (Figure 6), the top of both the arched bridge was originally built at elevation 843 - 844 ft. in 1874.

These scaled comparisons, as well as the photographic evidence of different construction materials for the subsequent overlying rail berm, showed that the late 19th or early 20th century grade had been raised to 854 - 855 foot. It also indicates that both the bridge area adjacent to the channel and the landfill behind the historic retaining wall were built up in a series of episodes between 1840 and 1900. These additions created a “layer cake” of buried historic surfaces, between the foundry retaining wall and the reservoir connected to the spur from the Morris Canal to the east, within the Access Road.

These vertical increments were matched by horizontal expansions in the extent of the landfill as well. Essentially, beginning in 1874, the southern shoreline of Furnace Falls Pond was extended outwards to the south to support the bridge abutment constructed over the then constricted channel. These horizontal expansions redefined the shoreline of the pre-1874 Furnace Falls Pond from a wide body of water to a restricted narrow drainage.

This horizontal landfill process appears to have reduced the original extent of Furnace Falls Pond by some 100 – 150 ft. north-south and its longitudinal extent by nearly 200 ft., or the distance between the 1874 bridge and the former cut-stone dam.

Accordingly, it can be projected that there is a high probability that early foundry-related structures may be present on one or more buried surfaces at around elevation 835 to 840 feet. Any future construction activities in the vicinity of the access road or behind the retaining wall should factor in this potential for the presence of preserved, buried historic surfaces as part of any mandated archaeological testing or evaluation of the National Register eligible historic foundry complex.

In essence, these vertical and horizontal additions of land fill transformed the original topography behind the cut-stone dam. From a large open pond emerged an artificially created channel after the 1874 addition of the arched stone bridge.

These elevation projections or reconstructions also dovetail with the form and size of the original Furnace Falls Pond as depicted in the 1828 and 1858 maps of the original Furnace Pond configuration (Figures 2, 3 & 4) prior to the advent of the upriver installation of the 1874 arched cut-stone bridge.

Chronological and Material Correlations

Finally, in addition to these elevation-derived correlations, the relative contemporaniety of different components of the site is further indicated by contrasts and parallels in the workmanship and lithic materials used to construct the site.

As documented photographically (Figure 28), the workmanship and type of stone encountered in the earliest, 1830 - 1840 era Furnace Falls dam appears to be similar, if not identical, to that found associated with the heavy cut-stone wall. Both structures are also characterized by similar, if not identical, finishing on the corner treatments. Both appear to have been made out of similar tan to red sand or limestone materials.

In contrast, the stone work, associated with the post-1874 cut-stone bridge abutment and eastern wing walls, was a visually distinct grey metamorphic material of apparently different origin.

Site Documentation Procedures

Four systems were used to record the site complex to meet the NJ State Historic Preservation Office standards and guidelines for the documentation of National and State Register eligible resources:

(1) The recently developed true-color Riegl LIDAR (laser-radar, or Light Detection And Ranging) system operated by Naik Prasad Inc. to capture a 3D record of the site with a point resolution of 6 mm (i.e., an averaged resolution of 1/100th ft.),

(2) Measured and drawn field plan and profile sketches (access road) where accessible,

(3) An EDM (Electronic Distance Meter) or Total Station computer transit for coordinate and elevation measurements, in use since the 1980's,

(4) A high resolution single camera Rolleimetric photogrammetry system to record high resolution metric, or flat field, film-based records of each major feature.

Grid and datum control for the LIDAR scan was established with a high resolution GPS system capable of "on the fly" setting of coordinate points through field transponders receiving signals from geospatial positioning satellites.

LIDAR: 3D Laser Imaging Sensor

LIDAR (Light Detection And Ranging) is not new, but it is rapidly evolving as a unique recording technology and as a viable tool for archaeology. Over the last decade, archaeologists and architects throughout the world have used computer modeling to depict and reconstruct historic and ancient sites. LIDAR was applied to record threatened National monuments such as the Statue of Liberty, at Ground Zero to record the "Pile", and to map and engineer the Second Avenue Subway (Grossman 2003a, Lapointe 2001, 2002, Louden 2002, Moltenbray 2001), to give a few examples.

3D color-encoded LIDAR was selected because it was the only technology that held the promise of being able to record a site of this size and internal variation under dangerous conditions in a fraction of the traditional time frame, in hours rather than days.

Whereas standard archaeological field programs generally divide time and effort equally between exposure or discovery and recording, the challenges posed by the need to dewater and then hold back upriver stream flow in this case reduced the ratio for recording to about 1/5th of the field exposure time. Access for recording was calculated in time slots of minutes, at most several hours, instead of days. This new release was able to encompass scan areas over 360^{o} horizontally and 90^{o} vertically with each set-up. This expanded visibility, in essence, doubled the rate of data coverage over the earlier generation of systems.

The other reason for the selection of LIDAR was safety. In addition to its speed and precision (i.e. 12,000 points / second), the LIDAR provided a remote (non-contact), safe, and highly accurate means to measure form, dimensions and precise coordinates of difficult to reach or dangerous structures, such as those exposed at Furnace Falls.
Unlike traditional manual measurement and mapping, and even unlike electronic transit systems and photogrammetry requiring a person to place targets and/or reflecting range pole prisms over features, the LIDAR can be deployed from a safe base station. It can be located up to 200 yards from areas of potential instability.

In this Phase II data recovery investigation, no option existed to place field personnel on, near or under the precariously exposed wing walls or ice-covered dam surface. Human contact was limited to the placing of scales on or against the individual features and the preparation of the top of the dam structure, which was brushed clean by two experienced machine operators for a period of less than 30 minutes. All other documentation activities were done at a distance of 30 to 75 ft. from the deeply exposed structure (See R. Tamblyn, 2004, for discussion of LIDAR as a safe approach to capturing metric data on bridge structures). At Furnace Falls, with the increasing depth of the dam, the remote and non-contact capabilities gained in importance.

The LIDAR scan was achieved with 11 equipment setups (Figure 16, NPI-Plan 6/6) which were recorded for about 15 minutes each. Three scans were taken at each position and averaged.

The balance of the six hour scanning session was taken up with breakdown, transport and reassembly of the equipment, as well as coping with the nagging problems of maintaining constant supply of battery power in the extreme cold.

Arctic temperatures hovering in the teens and low twenties during the fieldwork reduced normal battery life to minutes for the digital cameras and small appliances. The LIDAR was powered by independent dedicated power packs that were rated by the manufacturer to power 12 scans per battery change. At the site, however, each LIDAR pack lasted for no more than three scans before having to be changed.

The decision to use LIDAR to address the time and safety issues presented by the mitigation of Furnace Falls followed a multi-decade series of earlier solutions the PI had applied in other large scale emergency excavation projects. These included computer transits, stereo and single camera photogrammetry as well as earlier generations of the LIDAR system when they first became available in 1998 (Grossman 2003b). The selection process focused first on the availability of the most advanced and newest systems in the US and then on the availability on a seasoned engineering and survey team to go with it.

The author had been faced with the challenges of using a new and emerging technology in a 1999 emergency recording project for the State of New York in Albany, in which both single camera photogrammetry and an early prototype release of the newly developed LIDAR system were used (Grossman 2003b). Designed to survey oil platforms characterized by uniform forms and tubing at sea, as a joint venture between Chevron and DARPA, the fledgling technology proved less efficient when confronted with irregular organic forms such as hand-cut logs encountered in the Albany excavation. At that time, the LIDAR proved to be less successful as a prototype technology than single-camera photogrammetry from a 100 ft. cherry picker (ibid).

The Furnace Falls mitigation and emergency recording project five years later benefited from subsequent advances in both hardware and software. An essential aspect in the successful application of the LIDAR was a recent breakthrough in the technology that permitted the recording of 3D space in real world color. This advance became possible through the successful computer-integration of high resolution digital photography with the coordinate-based LIDAR scanning system. This critical innovation in systems integration was made available in the summer of 2003 by LIDAR manufacturer, Riegl Laser Measurement Systems of Austria.

The Furnace Falls mitigation constituted the first deep winter archaeological deployment of this new generation of integrated 3D color radar scanning technology. The LIDAR was very fast and precise. It promised very high levels of accuracy (6 mm) with safe, i.e. remote, measurements at a rate of data collection (12,000 points per second) fast enough to beat the rising water.

True-Color 3D Documentation

In addition to speed and safety, the fact that this was the first LIDAR generation to offer integrated true-color data capture was a third motivating factor for the selection of this generation and model. This hardware innovation came attached to a computer controlled, high resolution, 6 mega-pixel Nikon digital camera with a wide field macro lens (Figures 1 c-d & 16). During each sideway sweep, the integrated camera took some 10 to 13 overlapping images, each locked into the location of the instrument and to the coordinate control targets throughout the survey zone of the site (Figures 27, 43 & 44).

Newly available advances in software control and post-processing capabilities allowed for the integration of each LIDAR scan, or point cloud, with digital color images taken in tandem with the laser radar. Each color pixel of the digital images was paired, pixel by pixel, with the recorded coordinate points of the LIDAR. This new capability replaced the previous practice of assigning arbitrary, or artist-selected, color schemes or pre-rendered digital image textures. This breakthrough permitted the first-ever capture of an archaeological site as a true color 3D computer model or, better, virtual reality reproduction.

This advance addressed a key deficiency in earlier attempts to use LIDAR scanning and computer modeling to reconstruct archaeological sites and monuments.

When applied to archaeological sites, both computer modeling and LIDAR renderings were consistently plagued by the problem of color, or, better, the only relative accuracy of the colorized computer model. All of these efforts had in common that the LIDAR signal returned images of relative light intensity, not true color. The raw LIDAR scans appeared as false color green-red or silvery mercury-like surfaces (Louden, 2002).

Until 2004, users were forced to use color samples from photographs or impressions of field staff to try to match and assign appropriate color to a computer-generated model, or to LIDAR scans. This approach in turn has raised concerns over the veracity of the final archaeological reconstruction.

Underscoring the problem, Harrison Eiteljorg, II, Director of the Center for the Study of Archaeology at Bryn Mawr, raised three issues of concern: (1.) The problem of "representing" versus "documenting", (2.) the problem that, in order to be useful, the presented modeling needed to show data in a form that permits others to query the model or investigate unaddressed aspects of it, and (3.) that even though the original LIDAR data is precise, there is a large potential for subjective filtering of the data during transfer into standard engineering CAD systems by human operators (See H. Eiteljorg, II, "The Pitfalls of Virtual Archaeology", CGW, September 2001; "The Compelling Computer Image – a double-edged sword", Internet Archaeology, August 2000).

The new Riegl LIDAR, with its first generation integrated digital color camera, substitutes true digital color image captures for humanly defined color matching or surface "texture mapping" (assigning a pre-defined color or pattern to a computer-generated form) as part of the modeling process. Instead of assigning some color as a laminate or surface map over the metallic-looking raw LIDAR measurements, with the new Riegl LIDAR system, each color pixel is matched to its corresponding coordinates of the LIDAR point data to render what the LIDAR and digital camera actually "saw" in true color (Figures 45 - 54).

Isolating Historic Components

Finally, the ability of the LIDAR scanner to "see under and around" major obstructions by linking the results of various scan positions added an important capability to the site documentation process. At the outset of the fieldwork, it was thought that the temporary wooden bridge for providing access to both sides of the channel during construction would have to be dismantled to provide clear, unobstructed, lines of sight for the LIDAR scanner. The software's capability to seam together different scans from different angles made the costly task of taking down and rebuilding the construction bridge unnecessary. Instead, multiple scans from either side of the bridge were stitched together with the system software into a single point cloud of LIDAR measurements. This saved the client at least three days of construction time, if not more.

The new LIDAR software also permitted the 3D removal and cutting out of all modern obstructions or recent land form changes so as to isolate and depict only the targeted historic elements. For example, the LIDAR saw the blanket of snow over the site as formless white background (Figure 45).

The modern terrain was also not the subject of the data capture. It had been altered several times since the floods of 2001 and then extensively sculptured to provide access ramps and berms around and across the site as a prelude to both the archaeology and construction. As none but the historic elements were of concern, the Naik-Prasad LIDAR technicians were instructed to extract and render only the 19th century and early 20th century components of the site. All modern items as well as the recent topography were isolated and rendered invisible. The result was a clean 3D capture of the site that presents the original historic structures - the dam, the weir and the channel walls - without modern artifacts from the most recent construction and site grading work (Figures 45 - 54).

Remote Virtual Investigation

Post-processing of the scanner point clouds also was turned around in a fraction of the traditional time frame. The raw LIDAR scans or point clouds were first registered and then geo-referenced for data extraction by the third week out of the field.

Before being able to extract elevations and dimensions from the measured scans, the technicians had to correlate the 11 different scan positions in 3D space by registering each of the raw scan or “point clouds” to common reflector targets in each view. Once integrated, the combined point cloud data was geo-referenced and re-projected into real-world coordinates set by the satellite GPS recorders to the New Jersey State Plane Coordinate system the previous day.

By February 17, the Naik Prasad LIDAR technicians started converting the raw scans into real-world geo-referenced true-color 3D models.

By February 26, they were ready to sit down with the project archaeologist to select the locations for the extraction of profile cross-sections and 3D views, all scaled and geo-referenced in feet and tenths and actual elevations above sea level. All coordinates of the historic features, dimensions and elevations were extracted from the LIDAR scan data after the fieldwork was finished.

The final task of the analysis involved the virtual investigation and documentation (with screen captures of raw LIDAR scans, extracted coordinates and dimensions) of areas and perspectives that were impossible to safely get close to in the field, such as elevated views 30 ft. in the air and close-ups under the overhanging slabs of unsupported cement spillway wing walls (Figures 22 - 24). Over the first week of March, the archaeological field director and the technicians revisited the site in 3D virtual space to “fly” through and over the site to capture detailed records of the various historic features of the channel that could not be investigated during fieldwork (Figures 45 - 54).

Real Time Datum Control – GPS (Geospatial Positioning Systems)

The LIDAR results can be only as good as the precision of the site’s datum or grid control. For this reason, LIDAR scans are taken in conjunction with various high-precision survey instruments, generally either a transit or a GPS satellite based location control system. At Furnace Falls, the ability of the LIDAR to capture the site in real world 3D coordinates depended entirely on the establishment of a tightly controlled grid of datum control points, each to 1/100th foot.

This baseline need posed a problem throughout the project, as previous survey datum control hubs set by the project engineers had been repeatedly destroyed. Points originally set in 2001 had been disturbed by, or lost because of, the intensive ongoing heavy-machinery grading and earth moving activates. During the initial access road fieldwork phase, it was necessary to resurvey into the site from distant surviving control points or survey hubs located at the south end of Furnace Road. These temporary controls were again lost during the subsequent laying of protective gravel and site grading activities in November and December.

Accordingly, the ability to re-establish new site datum controls "on the fly" was a critical criterion in the team selection process. The Manhattan-based engineering firm of Naik Prasad was selected because they maintained both the newest pre-selected LIDAR hardware systems and in-house high-resolution satellite positioning systems. This GPS hardware was capable of establishing "Third Order" datum control to a resolution of 1/100th ft. over the football field sized site within a matter of hours.

Three permanent hubs were established over a two-hour period on the morning of Tuesday, January 20th. The rest of the day was spent setting up geo-referenced, or mapped in, reflecting targets in preparation of the LIDAR scans scheduled for the following day (NPI-Plan 1/6).

These high speed GPS and survey capabilities were also used for mapping the historic post-1830 cut-stone retaining wall supporting the reservoir and canal spur leading from the Morris Canal, above the foundry site. The precise location of the wall was important because it was one of the few structures consistently visible in representation of the historic site, both in maps and in air photos.

Control points were previously limited to the immediate area of the channel and the south end of Furnace Road (none had been established for the middle and northern sections of the Compac Corporations property). This localized cluster of points in only one corner of the site rendered the digital rectification and dereferencing of available air photo coverage of limited accuracy and utility. Mapping the visible corners of the historic retaining wall provided sufficient coverage to geo-reference, or assign real world coordinates to, other areas of air photo coverage of the site, including the access road and the Morris Canal spur and reservoir.

The satellite and computer transit team established the actual coordinates and elevations of key intersections of the historic foundry retaining wall in two hours (Figure 28). These new controls also permitted the checking of the site survey points recorded by the author earlier as an independent means of rectifying and, where necessary, repositioning each surveyed location and feature to the resolution and precision of the most recent dual receiver Naik Prasad GPS equipment.

The Single Camera Rolleimetric System

The medium format film-based metric Rolleimetric camera has a 90 degree flat field automatic lens capable of recording wide angle undistorted photographs.

The system works by taking multiple views from various angles with a scale in the field of view. Post-processing, with now inexpensive computer photogrammetry software, permits the user to first correlate each view with the other and then to geo-reference elements in the image to real-world coordinates. Once geo-referenced, the user can extract dimensions and locations from the images.

The system was developed by the Rollei Corporation in the late 1980's for intelligence and disaster recording. It was first deployed in archaeology by the author at a Federal Superfund archaeological mitigation of a Cadmium-laced Civil War site, West Point Foundry, between 1989 – 1994 (Grossman, 1994, 1997, 2003). At Furnace Falls, the Rolleimetric system was deployed as a backup and partially redundant means to capture high resolution, metrically accurate true-color film images of the site. It was used in tandem with the computer transit to record the two 19^{th} century features on the access road in the Phase I work October (See Appendix I - Phase I End of Field Letter).

The film-based Rolleimetric initially produced traditional negatives and prints which were expensive to reproduce. For this report and to facilitate a more cost-efficient distribution, multiple views of the access road and channel features were scanned as high resolution and saved as 3 Mb image files. Each image file was enhanced through color correction and light range leveling and renamed to indicate its subject matter. For this report, each of the files has been reduced to 72 dpi screen resolution for convenient storage and import into photogrammetry software programs. These digital archive metric images are stored on Disk 1 as part of the inventory of field records.

Data Formats and Dissemination

Data Formats

With reference to the second point raised by Eiteljorg, II (2001), the issue of accessibility and interactivity has been addressed in this submission by including both the original raw data and a number of output formats designed to let others use, measure and investigate the results. As provided on the NPI DVD Disks III and IV, the geo-referenced color LIDAR data has been saved into several common CAD formats, including Autocad and Microstation files (dxf, dwg), as well as several 3D modeling file types, specifically 3D color *.obj and web-friendly VRML files.

In addition to this hard copy report on the methodology and findings of the data recovery effort, the PI has put together a digital Video (DV) “Field Log” of the applied technology for community and/or educational distribution.

The DV format also provides a vehicle to present close-up records of inaccessible components of the site and animated 3D LIDAR scans of the recorded remains. One of the animations shows a birds eye view of the all historic elements of the site, the second a detailed “fly by” of the historic cut-stone face of the dam and the third a close-up, 360 degree views and animations of the eastern end of the channel and the post-1927 weir.

Finally, this DV overview includes the close-up video captures of the profiled dam in section as well as the wooden footers at the base of the channel.

Data Dissemination

This report is submitted in two CDR disks, one containing an Adobe pdf file of the report, the DV Field Log and scanned image files from the Rolleimetric record of the access road channel features. A second CDR disk by the author includes a single file of the geo-referenced air photography of the Stanhope/Netcong area for use by other researchers. The Naik Prasad LIDAR data and results are reproduced and appended in two 4.7 Gb DVD disks.

Disk I: (CDR-Total 284 Mb): Four Folders: A. Digital Adobe pdf copy of Final Report Text and Appendices including an Adobe pdf copy of the November 2004 Phase I Access Road "End of Field" letter report. (32.8 Mb); B. Final Report Plates (pdf-18.3 Mb); C. Final (Rev1) LIDAR-derived measured CAD plans & profiles (Adobe pdf & DWG-98.7Mb); D. A Windows Media Player (WMV) version of the author's Digital Video Field Log of the project and its results – "The Archaeology of Furnace Falls" (171 Mb); Folder also includes a small 4 Mb WMV LIDAR animation of the 1830 Dam.

Disk II: (CDR-666 Mb): A single file disk containing a geo-referenced and reprojected digital image of a 1959 black and white air photo of the Stanhope/Netcong and Lake Musconetcong study area is saved as a GEOTIFF image with embedded coordinate data (NAD83 – UTM) at 1 meter, or ca.3 foot resolution(Robinson Aerial). File compatible with desktop GIS software packages for the extraction of coordinates and dimensions of visible features, such as the route of the Morris Canal through Stanhope.

Disk Set III (DVD-4.16 Gb) & IV (DVD-2.28 GB): Total: 6.44 Gb: Two DVD disks from Naik Prasad Inc. of LIDAR data and results. **Disk III** contains the GPS datum control settings, all LIDAR instrument sets up and control parameters, all raw and color-encoded scan data and all geo-referenced 3D color LIDAR reconstructions and images of the documented historic elements. Rendered 3D CAD and 3D color models are stored in a variety of exportable file formats: *Microstation* CAD *.dwg; STL, *.obj (a common color-encoded 3D modeling file), and as WRL web- friendly files. Four rendered 3D animations, or "fly byes", of the dam, channel and weir are included as digital AVI files. DVD **Disk IV** includes two 3D viewer programs (*Polyworks-Demo* and *RiView*) to manipulate the raw 3D color and geo-referenced 3D LIDAR scan captures and models. These can be used to explore the site in virtual space from viewing angles and positions which were inaccessible or too dangerous in the field.

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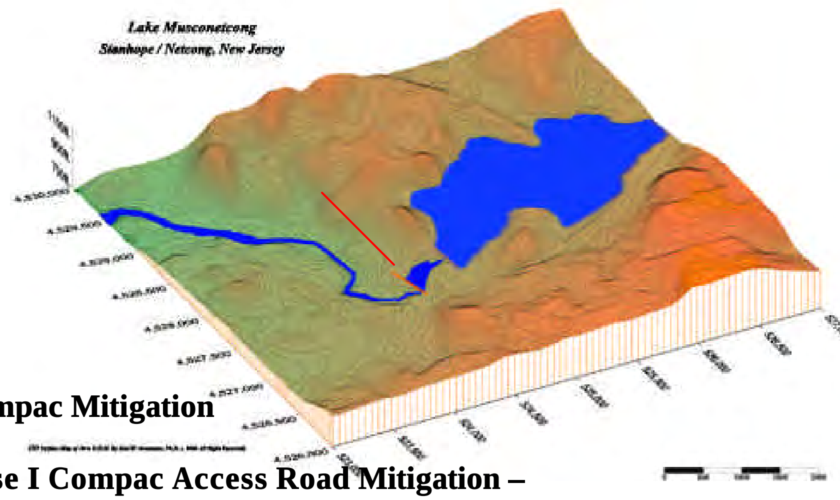
Appendix I

Phase I – End of Field Letter – Access Road Mitigation

JOEL W. GROSSMAN, PH.D.

520 WEST 218 ST., APT. 5G
NEW YORK, NEW YORK 10034
TEL: 212 942-3314

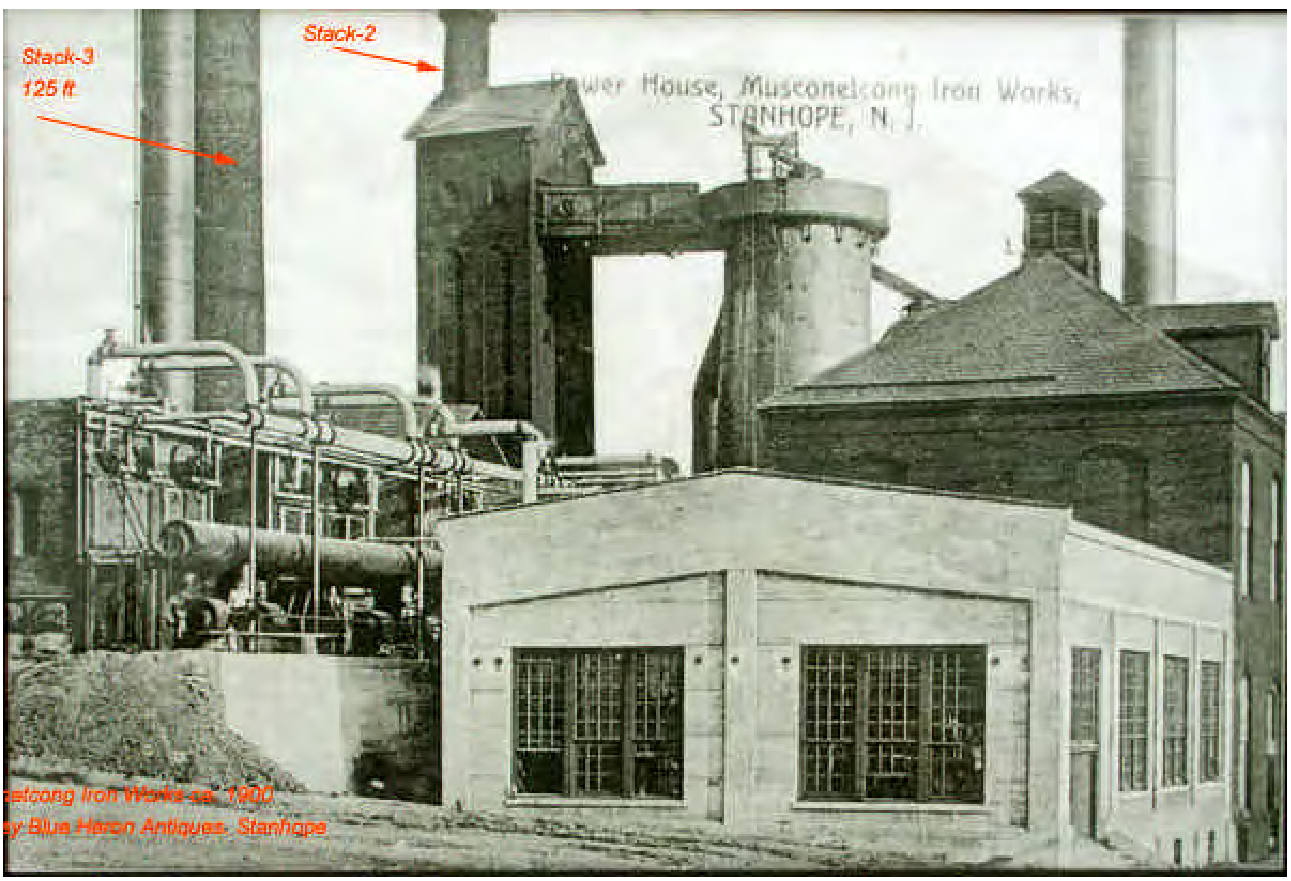


November 18, 2003

TO: **Dean DeGhetto**
Project Manager
Compac Corporation
Netcong, New Jersey

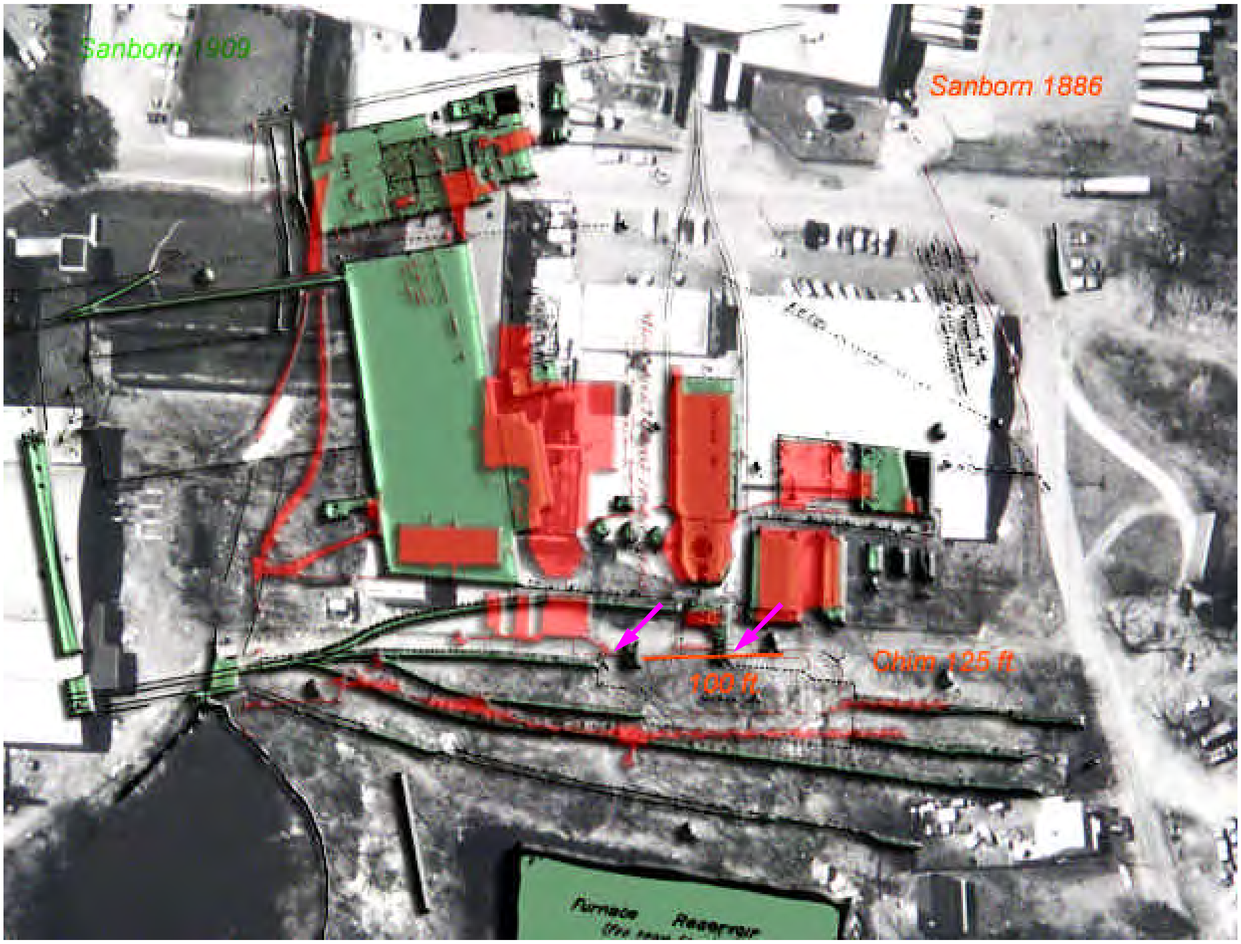
FROM: **Joel W. Grossman, Ph.D.**
Principal Investigator, Compac Mitigation

RE: **End of Field Letter – Phase I Compac Access Road Mitigation – Task Completion**



INTRODUCTION: I submit this End of Field report on the recently completed fieldwork on the Access (or, "Latex") Road into Compac property and Furnace Pond to substantiate my prior verbal representations that all field tasks and goals have been achieved for this first phase of the two stage scope of work and mitigation plan (Grossman, 2002) as mandated by the NJDEP Office of Historic Preservation and Dam Safety permit stipulations.

2. GIS AND AIR PHOTO BASED HISTORIC FEATURE LOCATION:



The goal of this first Phase I effort was to locate, identify, record and protect with reburial two historic foundation elements, designated Features II and III, belonging to mid nineteenth and early twentieth century foundry smoke stacks. Both will be in jeopardy from impacts due to subsequent heavy equipment construction activities across and within the Access Road which leads into production-critical tanker delivery and construction corridor routes for the Compac dam remediation program.

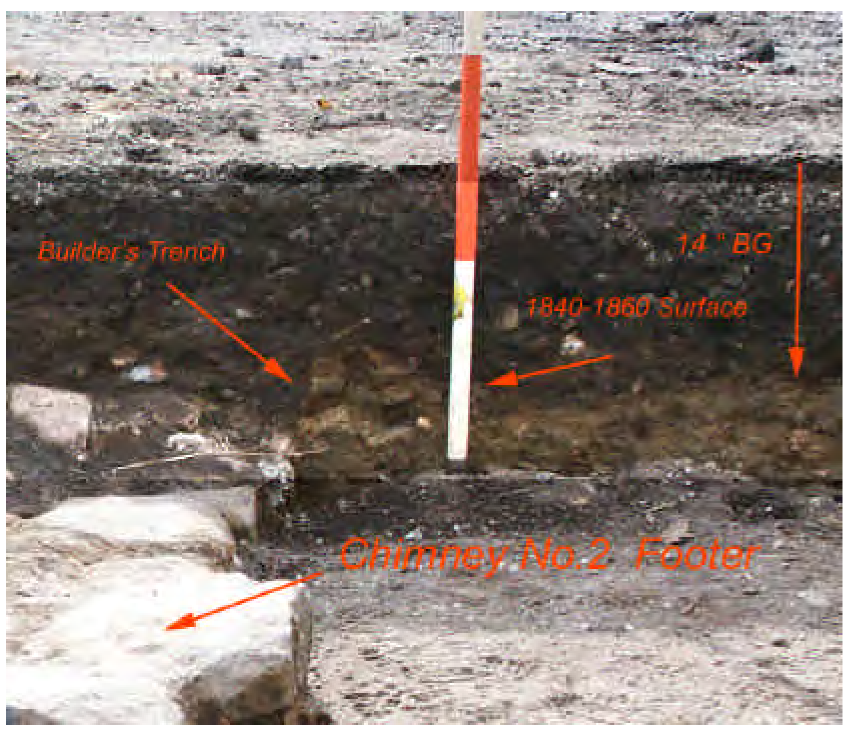
Both features were located and exposed as planned over a three day field period between Wednesday and Friday, October 29 – 31, 2003. Feature III, designated Stack 3, and consisted of the ca. 1900-1920 base of the third 125 ft. high foundry chimney of the Musconetcong Iron Works. Although only generally dateable from map sources, the recovery of four diagnostic fire bricks with well preserved makers marks will help refine its date of construction. Feature II, described as *Cobble Platform-Stack 2*, consisted of a massive stone and mortar foundation or footer base for the second chimney or associated rectangular stack structure built at the foundry. Both features had been initially identified as key structural elements on two historic Sanborn Insurance maps of the property dating to 1886 and 1909, respectively.

Their actual position was established by scaling two Sanborn Insurance maps as digital layers over a digitally enlarged subsection of a 1986 air photo of the site. The original 1=800 air photo was initially enlarged photographically to a scale of 1"=300 ft. by Robinson Aerial of Morristown, New Jersey. This print was then digitally enlarged to a scale of ca. 1"=60 ft. (1":58.8 ft – actual) as a 14 Mb image file by Joel W. Grossman and then overlaid as color coded digital copies of the 1886 and 1909 insurance maps. From this composite, the location and distance between each feature was measured on the ground and targeted for machine and manual exposure. Both features were located and exposed within five feet of their projected historic map-based locations.

3. FEATURE EXPOSURE AND DEFINITION

Half of the first feature, ***Feature III – Stack 3,*** the base of the 125 ft. circular brick and fire brick stack had survived as a surface outcrop in the road. The western half of the chimney base had been previously destroyed by unrelated remediation activities within the last 15 to 20 years. Enough of its form was exposed and recorded to reconstruct its original diameter and construction.

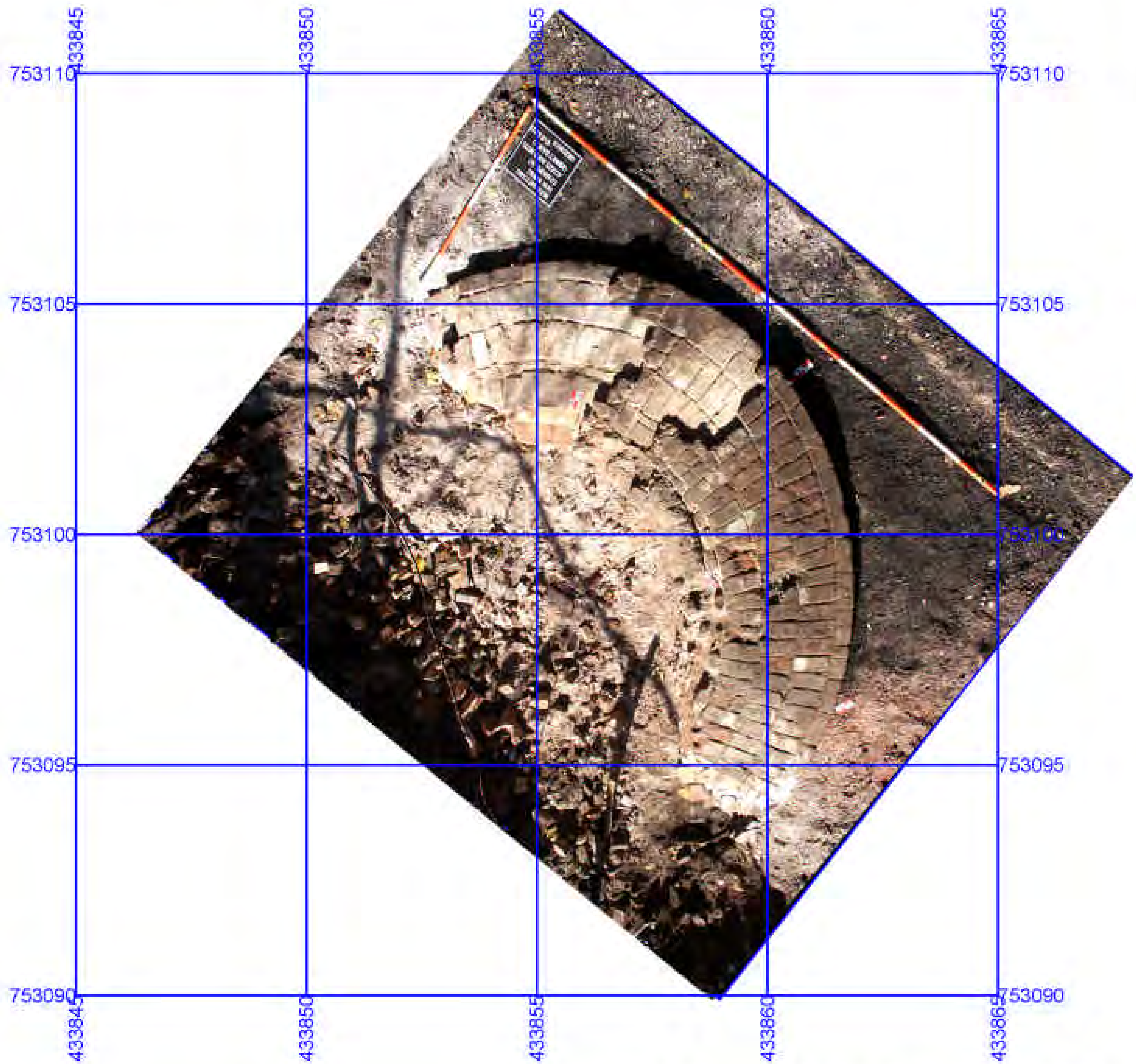
The second feature, ***Feature II – Cobble Platform - Stack 2,*** consisted of a large rectangular stone boulder and mortar foundation matrix exposed within the Access Road at a depth of 14 inches below grade. Approximately ¼ to ½ of its original size was exposed in a ca. 10 by 15 ft wide-area trench, sufficient to document its original size, shape and orientation.



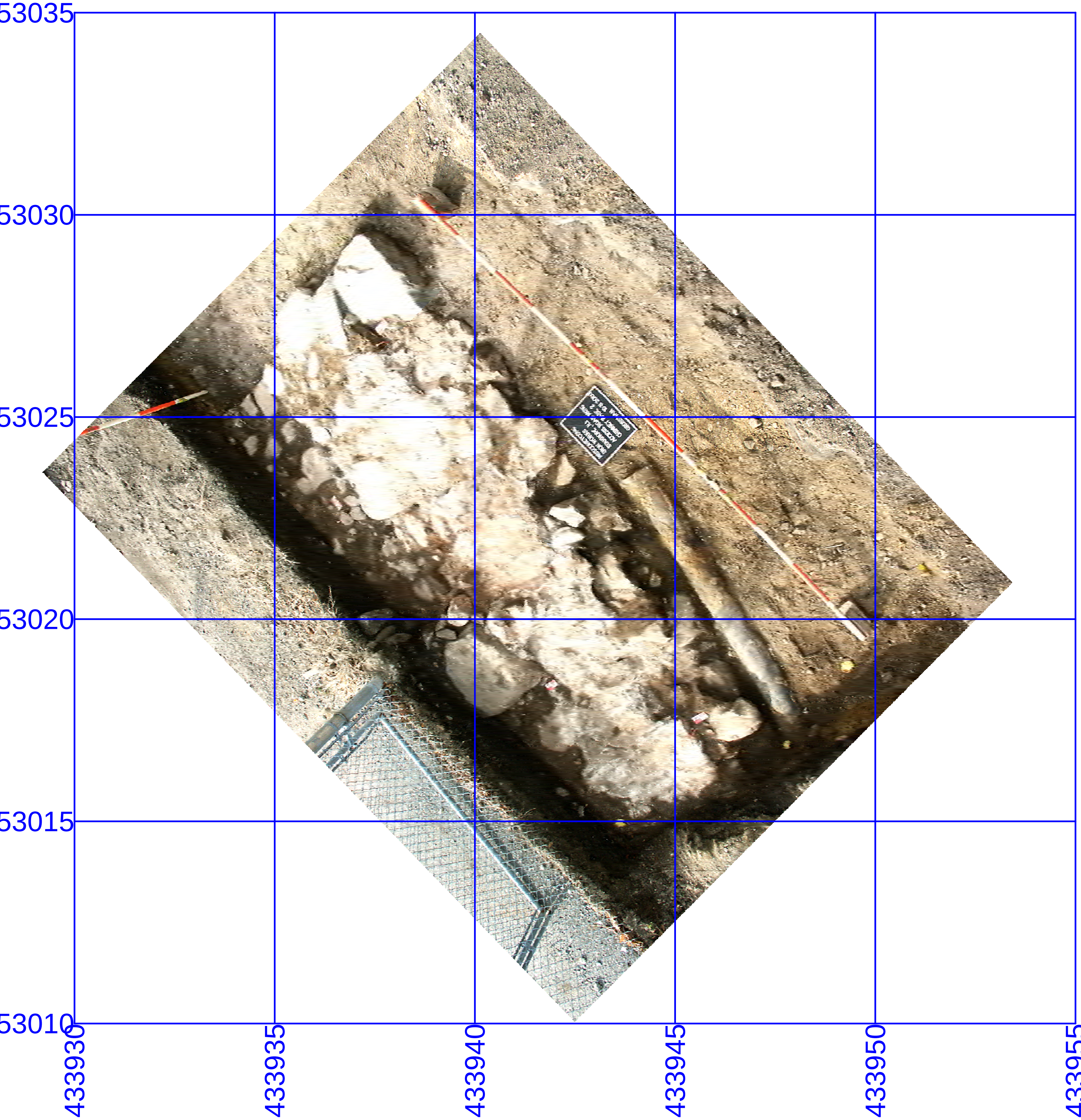
The stone footer platform was oriented ca 6 – 8 degrees off access with the modern road alignment, but parallel to the orientation of the post-1840 stone retaining wall which separated the lower foundry from the Morris Canal and spur to the foundry's reservoir above it.

Compac Access Road -Georeferenced Feature 3 - Chimney 3

New Jersey State Plane Coordinate System - NAD83



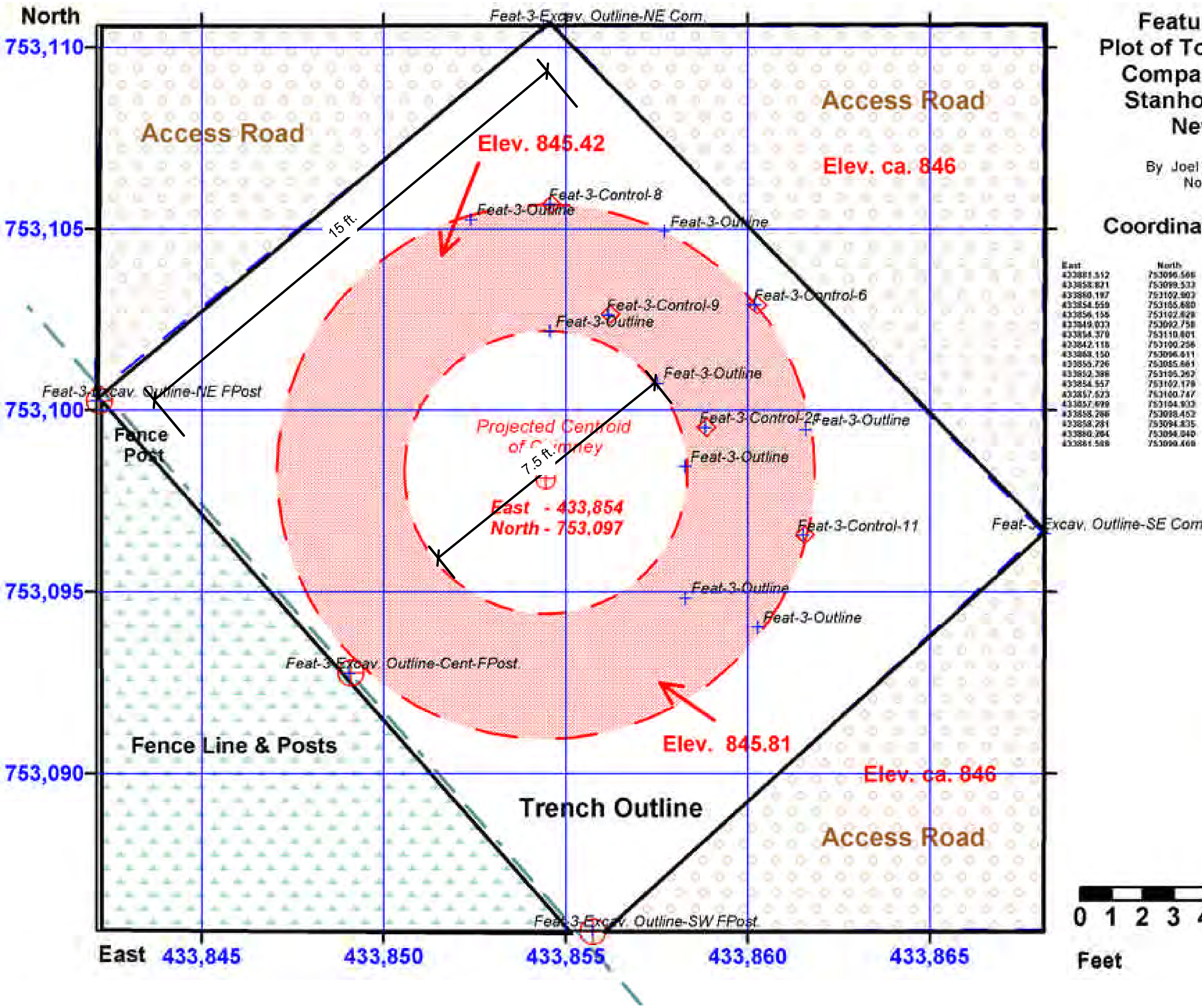
Compac Access Road- Feature 2 -Stone Platform-
New Jersey State Plane Coordinate System
Geotiff - NAD 83



November 2003

Feature 3 - Stack3
Plot of Total Station Data
Compac Corporation
Stanhope/ Netcong, New Jersey

By Joel W. Grossman, Ph.D.
November 9,2003



Coordinates & Elevations

East	North	Elev.	Point Id.
433861.512	753096.566	845.807	Feat-3-Control-11
433858.821	753099.533	845.754	Feat-3-Control-21
433860.197	753102.903	845.783	Feat-3-Control-6
433854.559	753105.680	845.42	Feat-3-Control-8
433856.155	753102.828	845.54	Feat-3-Control-9
433849.033	753092.758	846.386	Feat-3-Excav. Out.-Cent-FPost.
433854.379	753110.601	845.575	Feat-3-Excav. Out.-NE Corn.
433842.118	753100.256	845.728	Feat-3-Excav. Out.-NE FPost
433868.150	753096.611	845.94	Feat-3-Excav. Out.-SE Corn.
433855.726	753085.661	846.385	Feat-3-Excav. Out.-SW FPost.
433852.386	753105.262	844.896	Feat-3-Outline
433854.557	753102.178	844.752	Feat-3-Outline
433857.523	753100.747	845.823	Feat-3-Outline
433857.699	753104.933	845.593	Feat-3-Outline
433858.286	753098.452	844.946	Feat-3-Outline
433858.281	753094.835	844.897	Feat-3-Outline
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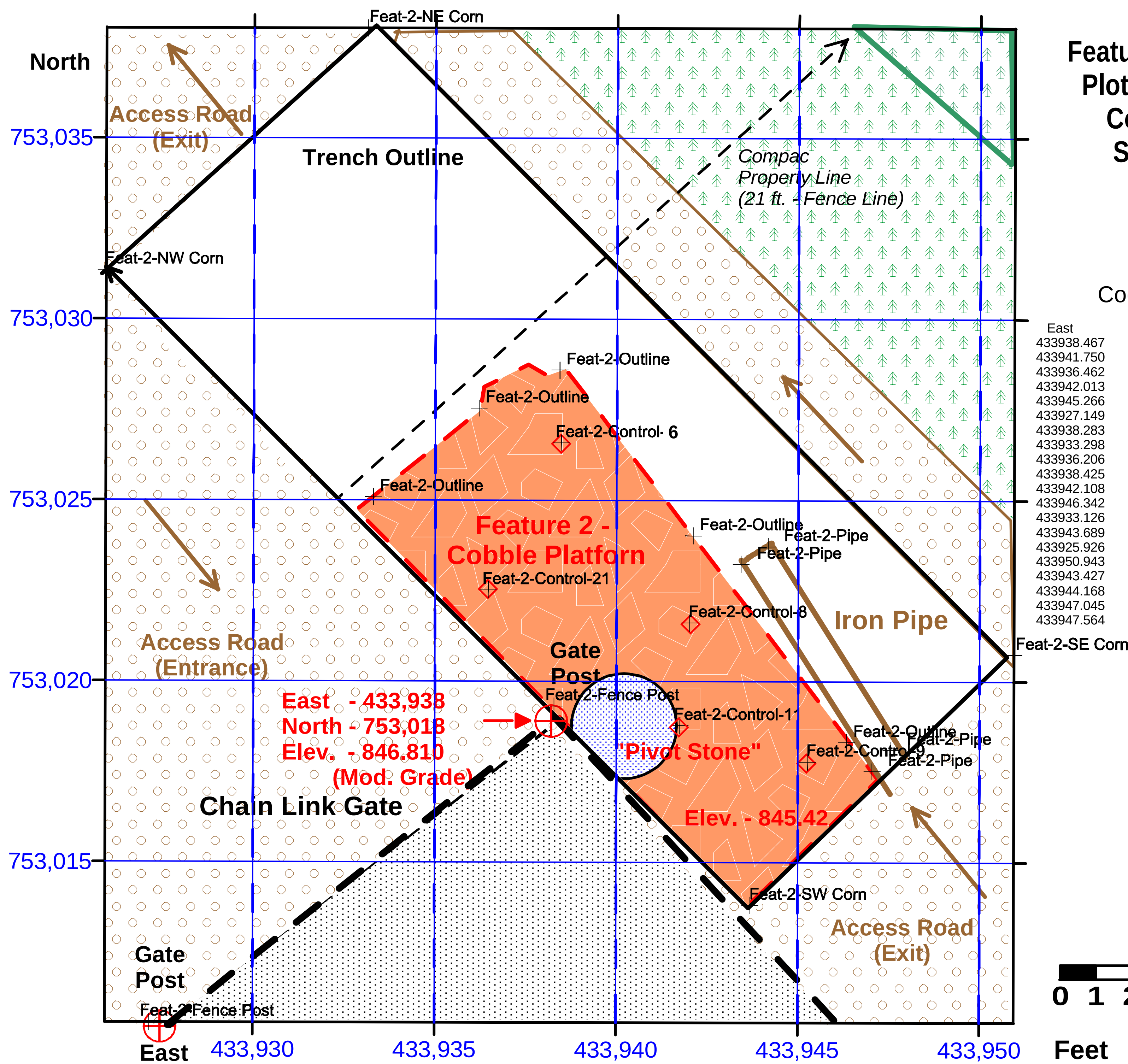
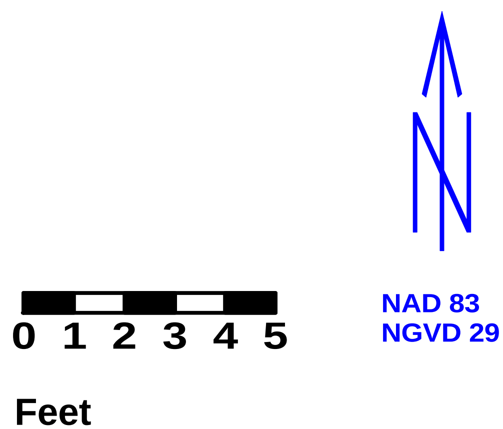


Feature 2 - Cobble Platform
Plot of Total Station Data
Compac Corporation
Stanhope/Netcong, New Jersey

By Joel W. Grossman, Ph.D.
November 8, 2003

Coordinates & Elevations

East	North	Elev.	Point id
433938.467	753026.586	845.406	Feat-2-Control-06
433941.750	753018.78	845.419	Feat-2-Control-11
433936.462	753022.521	845.712	Feat-2-Control-21
433942.013	753021.617	845.422	Feat-2-Control-8
433945.266	753017.784	845.289	Feat-2-Control-9
433927.149	753010.571	846.810	Feat-2-Fence Post
433938.283	753019.314	846.934	Feat-2-Fence Post
433933.298	753025.09	845.169	Feat-2-Outline
433936.206	753027.541	845.723	Feat-2-Outline
433938.425	753028.593	845.762	Feat-2-Outline
433942.108	753024.026	845.421	Feat-2-Outline
433946.342	753018.317	845.229	Feat-2-Outline
433933.126	753038.042	846.508	Feat-2-NE Corn
433943.689	753013.818	846.813	Feat-2-SW Corn
433925.926	753031.35	846.543	Feat-2-NW Corn
433950.943	753020.742	846.578	Feat-2-SE Corn
433943.427	753023.240	844.727	Feat-2-Pipe
433944.168	753023.729	844.733	Feat-2-Pipe
433947.045	753017.524	844.670	Feat-2-Pipe
433947.564	753018.112	844.733	Feat-2-Pipe



Phase I Compac Corporation Archaeological Mitigation
Edited Total Station Survey Data
Surveyed 11-01-03 JWG

East	North	Elev.	Label	Description
				Datums
433,539.065	752,991.289	818.729	Station-3011	AA-Datum-3011
433,647.975	753,228.052	831.286	Station-3012	AA-Datum-3012
433,679.898	753,282.516	834.657	Station-3013	AA-Datum-3013
				Access Rd -Ret. Wall
433,782.087	753,166.164	841.779	ACCESS-GATE	Access Rd. Gate Post
433,795.409	753,179.373	841.518	ACCESS-GATE	Access Rd. Gate Post
433,728.157	753,261.166	838.717	BW	Access Rd-BRW
433,744.053	753,241.323	838.528	BW	Access Rd-BRW
433,778.092	753,202.142	840.669	BW	Access Rd-BRW
433,802.126	753,176.185	842.976	BW	Access Rd-BRW
433,718.699	753,271.795	839.672	TW	Access Rd-TRW
433,745.600	753,241.289	843.078	TW	Access Rd-TRW
433,768.699	753,213.848	843.614	TW	Access Rd-TRW
433,802.563	753,180.255	845.814	TW	Access Rd-TRW
				Fence
433,629.659	753,131.634	823.636	FENCE	Chain Link Fence
433,634.794	753,112.615	822.185	FENCE	Chain Link Fence
433,690.413	753,205.179	832.950	FENCE	Chain Link Fence
433,711.527	753,184.296	833.450	FENCE	Chain Link Fence
433,739.080	753,208.570	838.395	FENCE	Chain Link Fence
433,807.581	753,136.357	843.597	FENCE	Chain Link Fence
433,889.100	753,051.015	846.643	FENCE	Chain Link Fence
434,060.975	752,893.947	850.835	FENCESOUTH	Chain Link Fence
				Mod. Comp Blds.
433,615.520	753,094.249	821.923	COMP-ENT	Comp. Bld-N Door
433,624.365	753,102.108	821.918	COMP-ENT	Comp. Bld-N Door
433,691.142	753,164.787	823.473	COMP-NEMETA	Comp. Bld-NE Corner-Metal Bld.
433,584.033	753,065.217	820.376	NWCORN-COMP	Comp. Bld-NW Corner-Brick
433,676.434	753,151.439	822.495	COMP-NEBRIC	Comp. Bld-NW Corner-Brick
433,710.455	753,144.083	824.520	COMP-METSE	Comp. Bld-SE Corner-Metal Bld.
				Feature 2
433,938.467	753,026.586	845.406	PLAT2-6	Feat-2-Control-6
433,941.750	753,018.780	845.419	PLAT2-11	Feat-2-Control-11
433,936.462	753,022.521	845.712	PLAT2-21	Feat-2-Control-21
433,942.013	753,021.617	845.422	PLA2T-8	Feat-2-Control-8
433,945.266	753,017.784	845.289	PLAT2-9	Feat-2-Control-9
433,927.149	753,010.571	846.810	PLAT2-POST-	Feat-2-Fence Post
433,938.283	753,019.314	846.934	PLAT2-POST-	Feat-2-Fence Post
433,933.298	753,025.090	845.169	PLATOUT	Feat-2-Outline
433,936.206	753,027.541	845.723	PLATOUT	Feat-2-Outline
433,938.425	753,028.593	845.762	PLATOUT	Feat-2-Outline
433,942.108	753,024.026	845.421	PLATOUT	Feat-2-Outline
433,946.342	753,018.317	845.229	PLATOUT	Feat-2-Outline
433,933.126	753,038.042	846.508	PLATOUT-NE	Feat-2-NE Corn
433,943.689	753,013.818	846.813	PLATEX-SW	Feat-2-SW Corn
433,925.926	753,031.350	846.543	PLATOUT-NW	Feat-2-NW Corn
433,950.943	753,020.742	846.578	PLAT-SE	Feat-2-SE Corn

433,943.427	753,023.240	844.727	PLATPIPE	Feat-2-Pipe
433,944.168	753,023.729	844.733	PLATPIPE	Feat-2-Pipe
433,947.045	753,017.524	844.670	PLATPIPE	Feat-2-Pipe
433,947.564	753,018.112	844.733	PLATPIPE	Feat-2-Pipe
				Feature 3
433,861.512	753,096.566	845.807	CH3-11	Feat-3-Control-11
433,858.821	753,099.533	845.754	CH3-21	Feat-3-Control-21
433,860.197	753,102.903	845.783	CH3-6	Feat-3-Control-6
433,854.559	753,105.680	845.420	CH3-8	Feat-3-Control-8
433,856.156	753,102.629	845.540	CH3-9	Feat-3-Control-9
433,849.033	753,092.758	846.386	EX-CENTPOST	Feat-3-Excav. Outline-Cent-FPost.
433,854.379	753,110.601	845.575	EX-NE	Feat-3-Excav. Outline-NE Corn.
433,842.118	753,100.256	845.728	EX-NE-POST	Feat-3-Excav. Outline-NE FPost
433,868.150	753,096.611	845.940	EX-OUT-SE	Feat-3-Excav. Outline-SE Corn.
433,855.726	753,085.661	846.385	EX-POSTSW	Feat-3-Excav. Outline-SW FPost.
433,852.386	753,105.262	844.896	CH3-OUTLINE	Feat-3-Outline
433,854.557	753,102.179	844.752	CH3-OUTLINE	Feat-3-Outline
433,857.523	753,100.747	845.623	CH3-OUTLINE	Feat-3-Outline
433,857.699	753,104.933	845.593	CH3-OUTLINE	Feat-3-Outline
433,858.266	753,098.453	844.946	CH3-OUTLINE	Feat-3-Outline
433,858.281	753,094.835	844.897	CH3-OUTLINE	Feat-3-Outline
433,860.264	753,094.040	845.378	CH3-OUTLINE	Feat-3-Outline
433,861.589	753,099.469	845.791	CH3-OUTLINE	Feat-3-Outline
433,861.603	753,099.455	845.792	CH3-OUTLINE	Feat-3-Outline
				Topo
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433,552.087	753,075.189	819.339	FURNRD-TOPO	Topo
433,558.034	753,025.758	818.874	FURNRD-TOPO	Topo
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433,562.241	753,038.814	819.043	FURNRD-TOPO	Topo
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433,693.978	753,207.620	834.921	TOPO	Topo
433,699.801	753,209.320	835.492	TOPO	Topo
433,701.477	753,264.658	834.262	FURNRD-TOPO	Topo
433,706.289	753,173.317	835.622	TOPO	Topo
433,706.924	753,191.390	836.524	TOPO	Topo
433,714.609	753,220.984	835.082	TOPO	Topo
433,724.214	753,181.433	838.036	TOPO	Topo
433,730.885	753,198.458	837.272	TOPO	Topo
433,816.769	753,152.930	843.319	ACCESSTOPO	Topo
433,822.581	753,129.455	844.418	ACCESSTOPO	Topo
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434,044.601	752,916.226	849.226	ACCESSTOPO	Topo
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Appendix II

Index of Rolleimetric Images


001-Dam Profile.tif


002-Dam-Profile.tif


009-Dam.tif


010-Dam.tif


011-Dam.tif


012-Dam.tif


001-Feat2.tif


002-Feat2.tif


003-Feat3.tif


004-Feat3.tif


005-Feat2.tif


006-Feat3.tif


007-Feat3.tif


008-Feat3.tif


017-Feat2.tif

014-Weir.tif

015-Weir.tif

016-Weir.tif

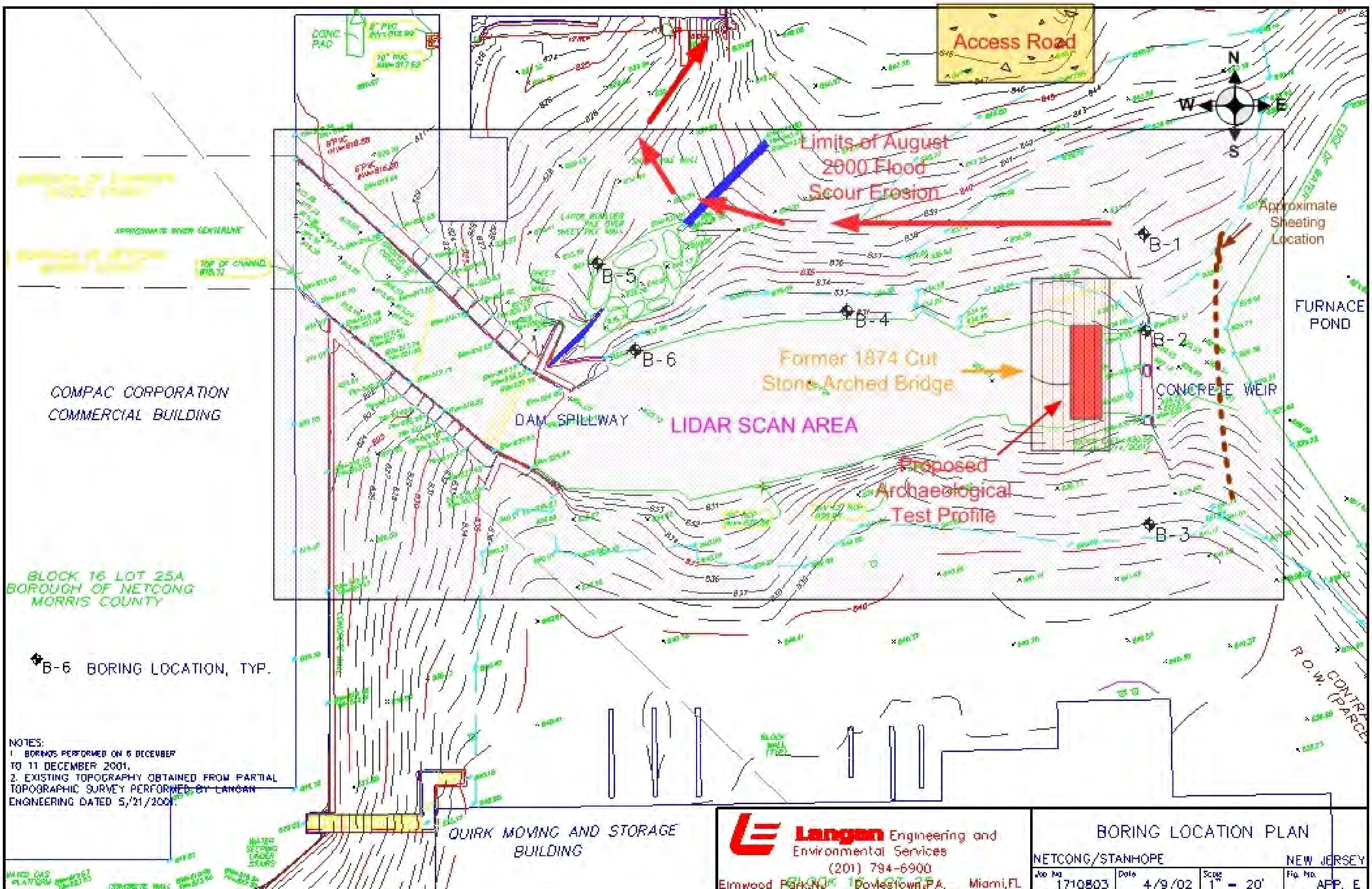


Figure 7. Project Plan of Furnace Pond Falls showing topography, zone of deep flood scour damage, locations of Langan test borings, proposed LIDAR 3D scan area, relocated sheeting plan, proposed N-S archaeological profile cut and former 1874 stone bridge.

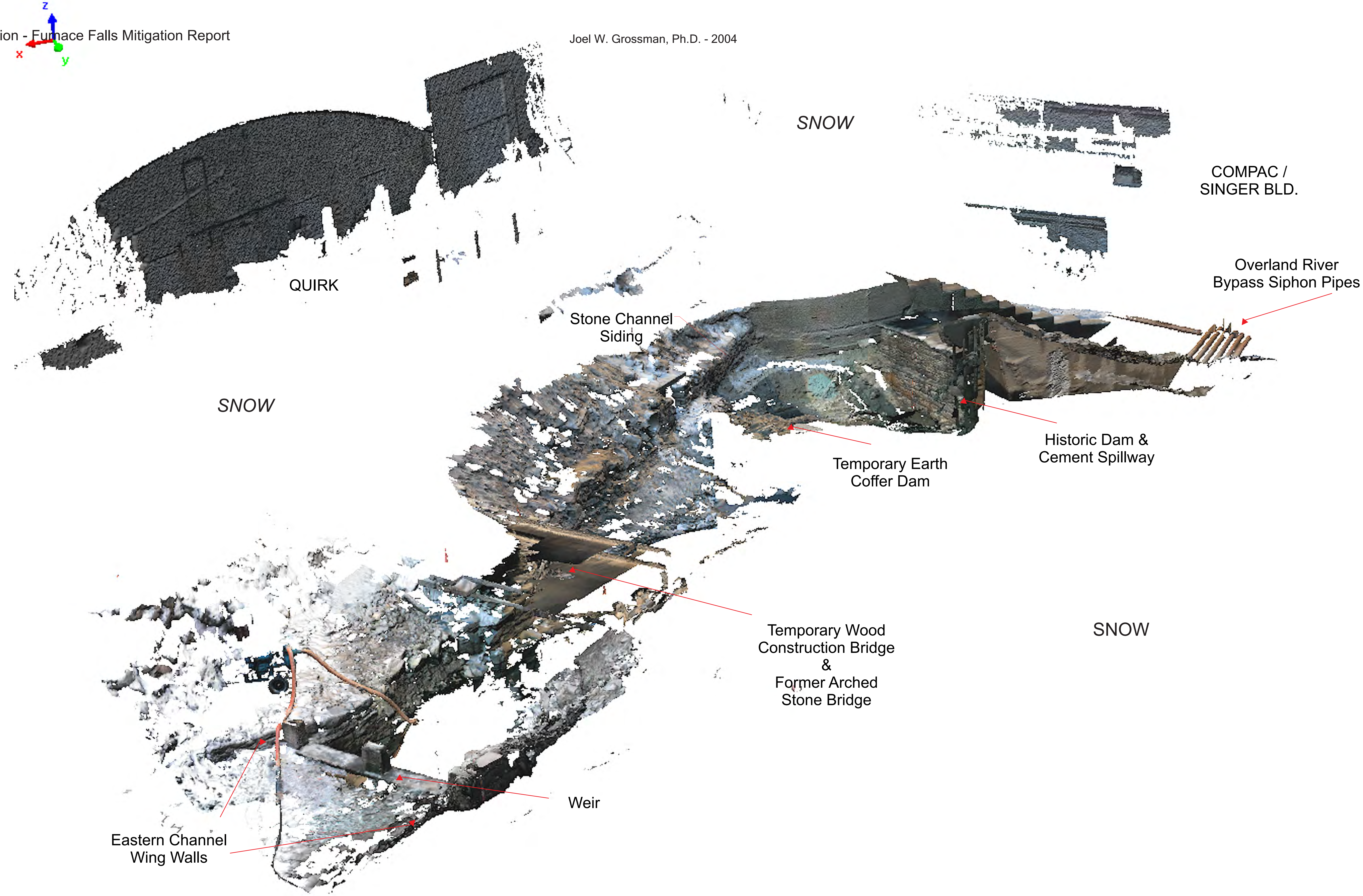


Figure 45: Overhead view, looking south-west, of eleven registered color LIDAR scans of the Furnace Falls channel, weir and Dam-Spillway recorded in six hours on January 21, 2004. Temperature range: 10 - 24 degrees F. Snow was "seen" as white.

Joel W. Grossman, Ph.D. - 2004

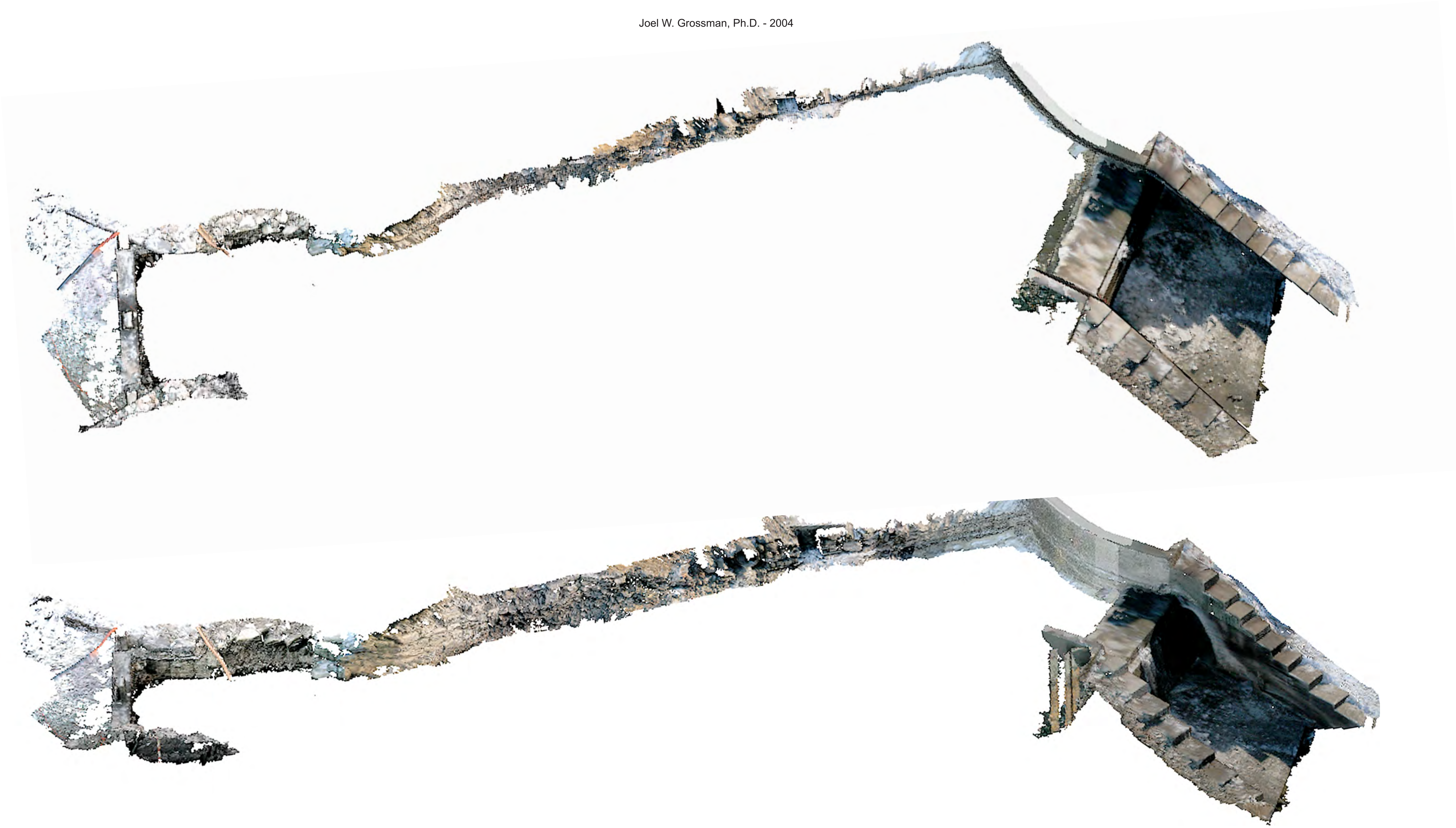


Figure 46: Overhead composite views of nine registered 3D color LIDAR scans of the Furnace Falls channel, weir and Dam-Spillway depicting only surviving historic features

Figure 47: Virtual 3D color LIDAR overhead perspective view looking east at western cement face of Singer Spillway, with southern bank of channel and weir to the rear.

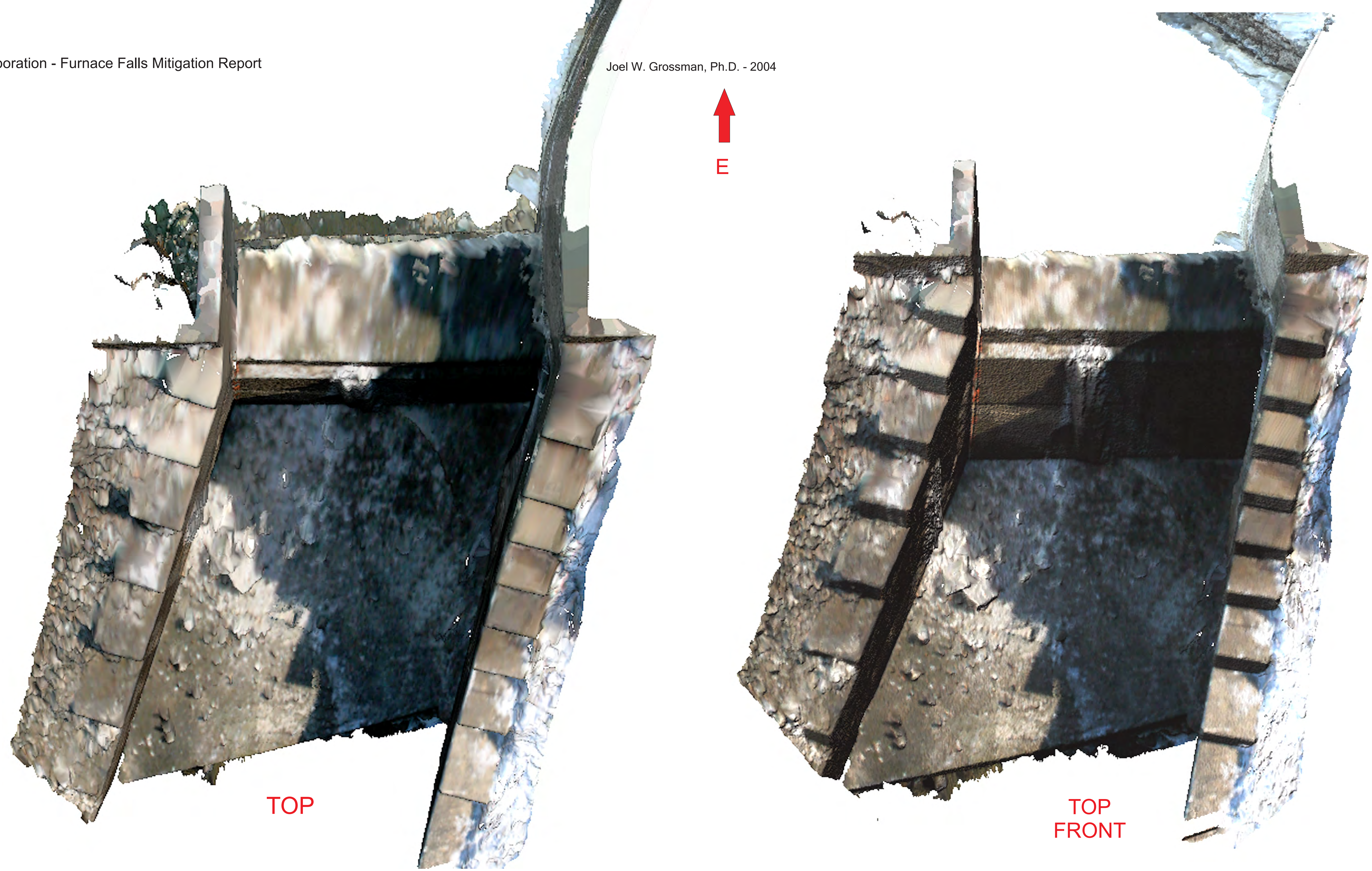
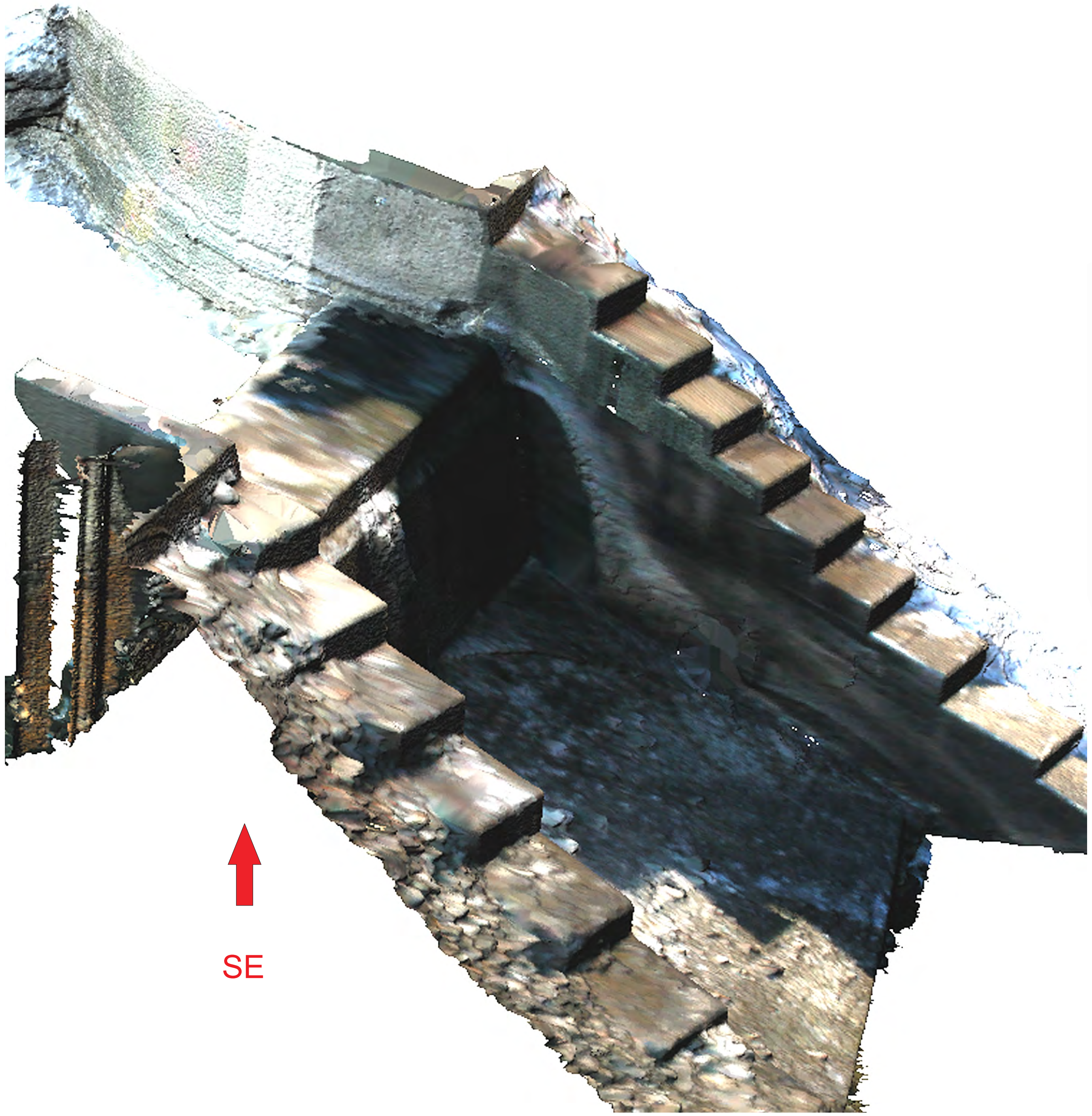


Figure 48: Two virtual 3D overhead views of the top and front (western) face of the recent cement Spillway additions to underlying early 1830 era cut stone dam.



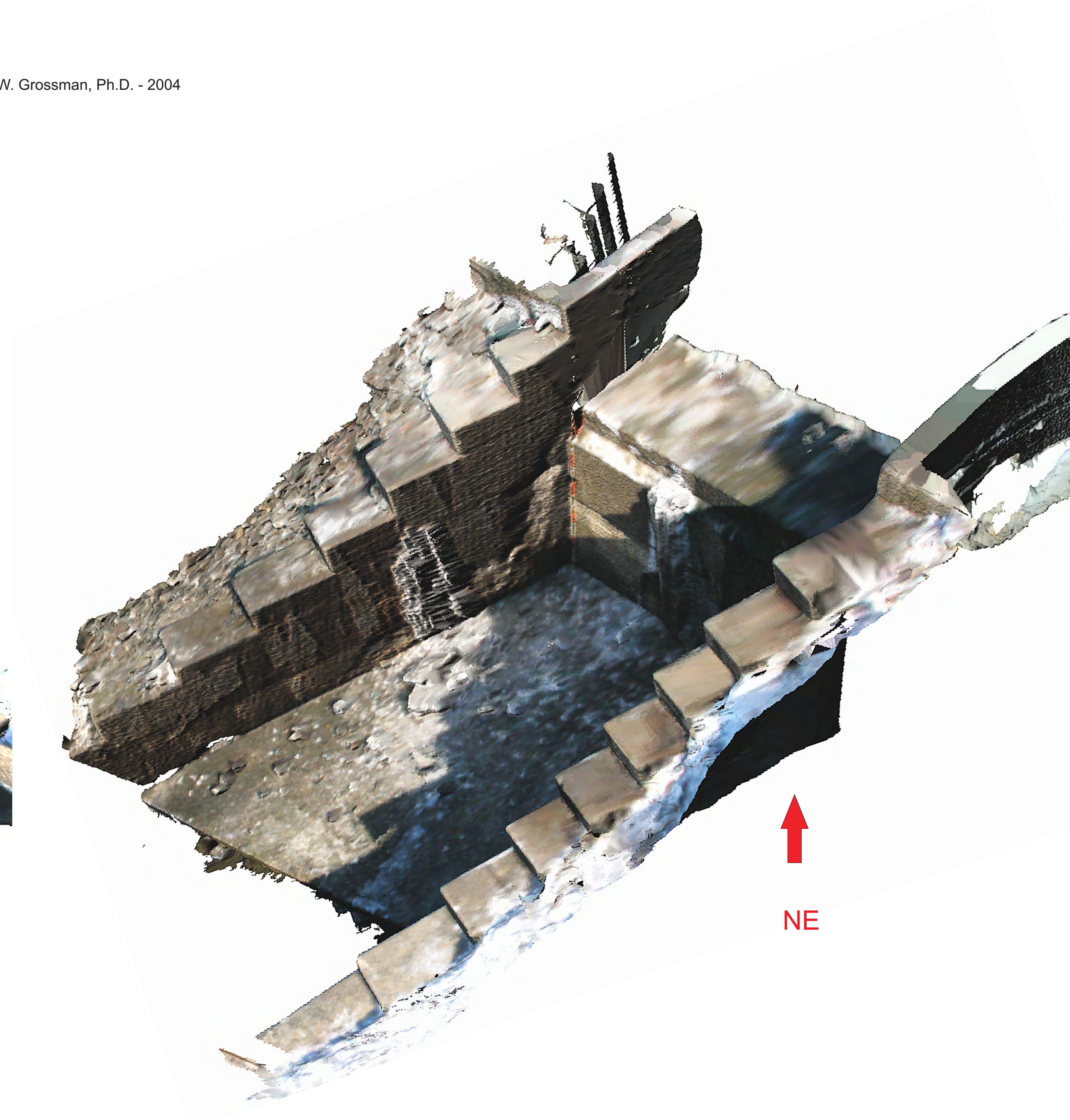


Figure 49: Two virtual overhead 3D color LIDAR scans looking southeast (left) and northeast (right) at the top and front (western) face of the most recent cement Spillway.

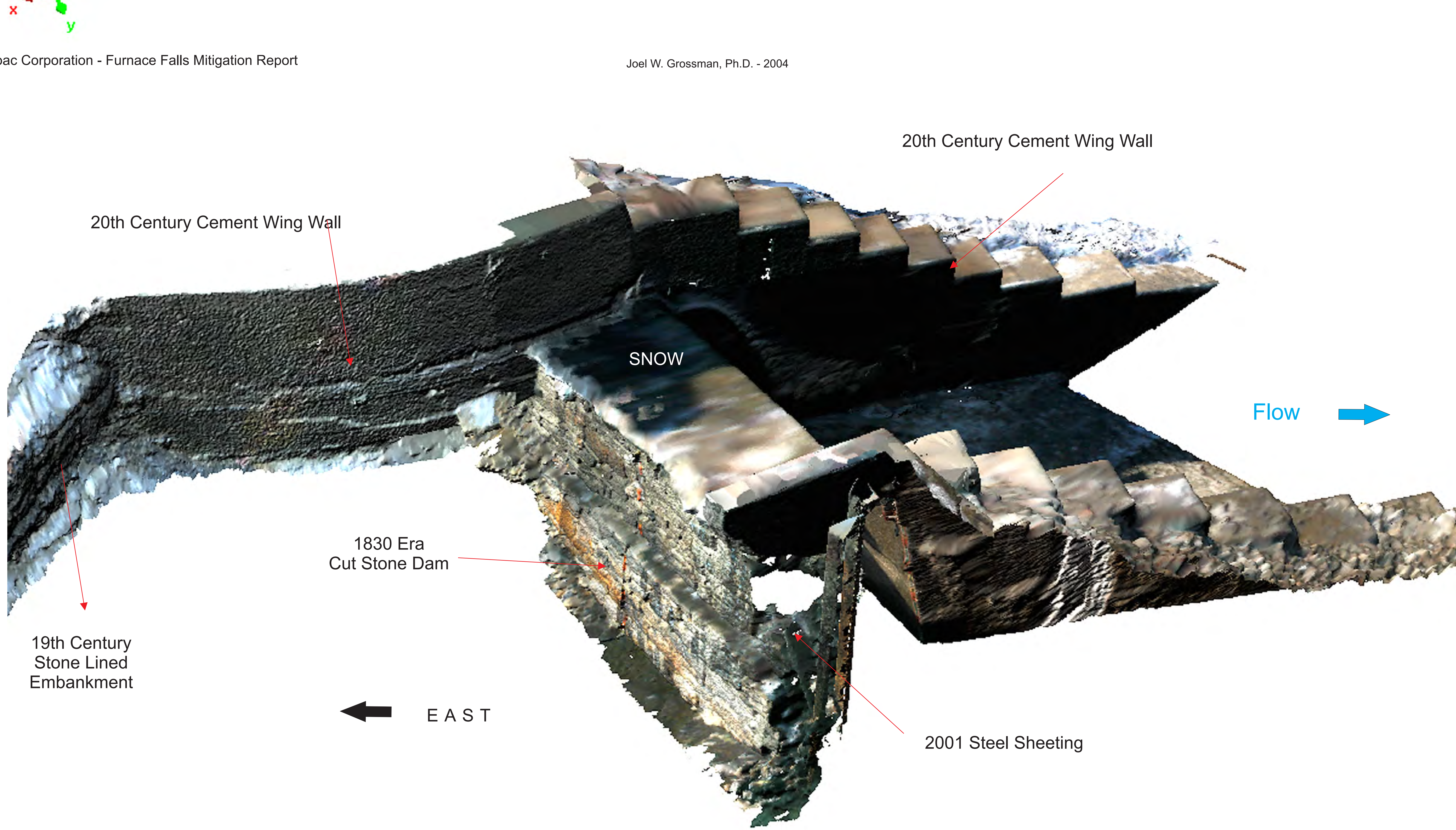


Figure 50: Virtual 3D Color LIDAR birds eye view of partially exposed historic Furnace Falls Dam, looking southwest and down from 50 ft., at its eastern cut stone face, later covered by 20th century cement cladding and cut into by cast cement wing walls.

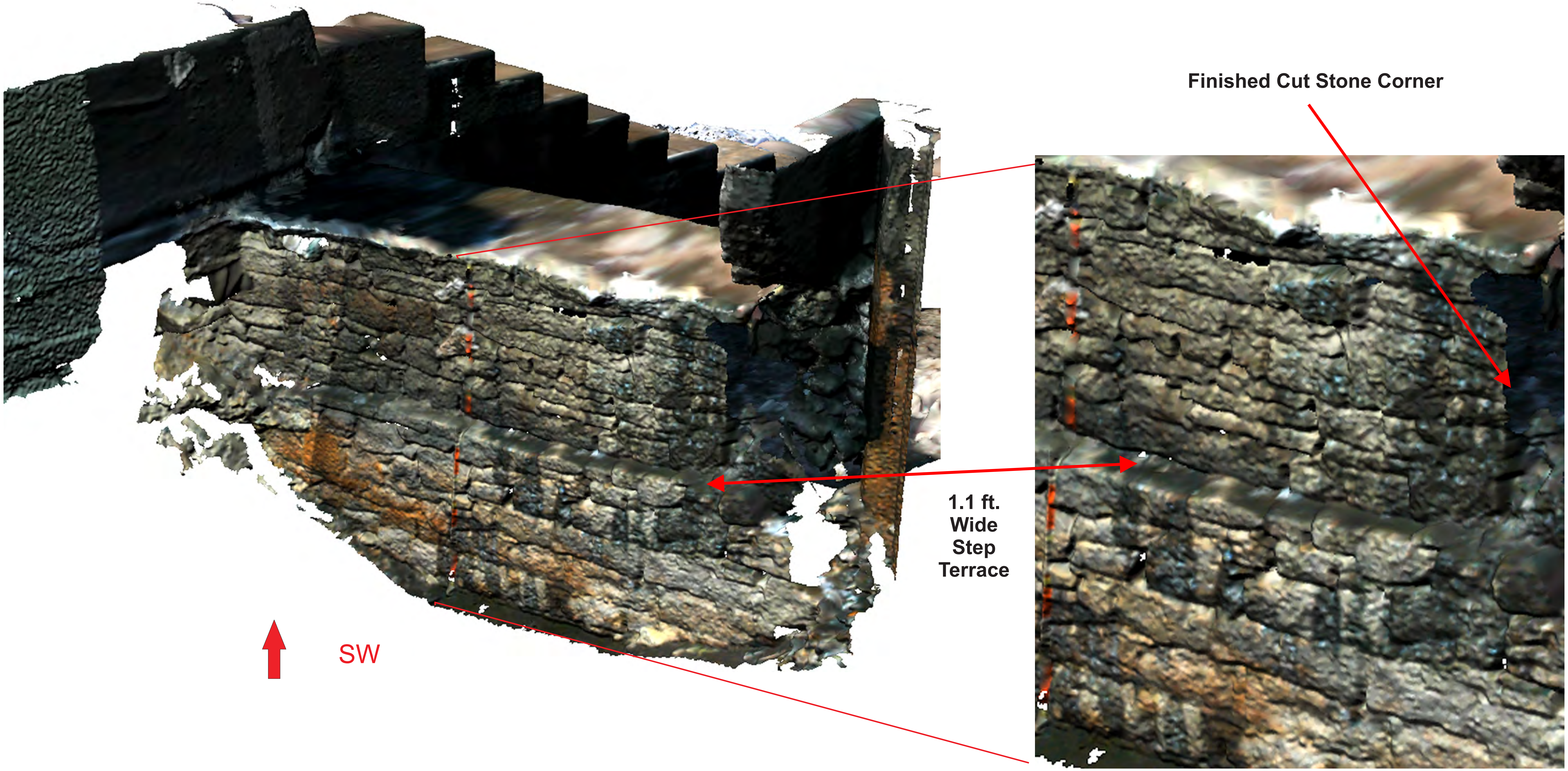


Figure 51: Virtual 3D color LIDAR perspective, looking south-west, highlighting finished northeast cut stone corner of historic Furnace Falls Dam. Although disturbed by the construction trenches and cement work of the later wing walls, the finished edge suggests a former, early 19th century, sluiceway to the north of the recently removed cement Spillway. The ability to “reinvestigate” the site in geo-referenced 3D color space provided otherwise unavailable access and proximity to areas of the dam too dangerous to approach during the excavation.

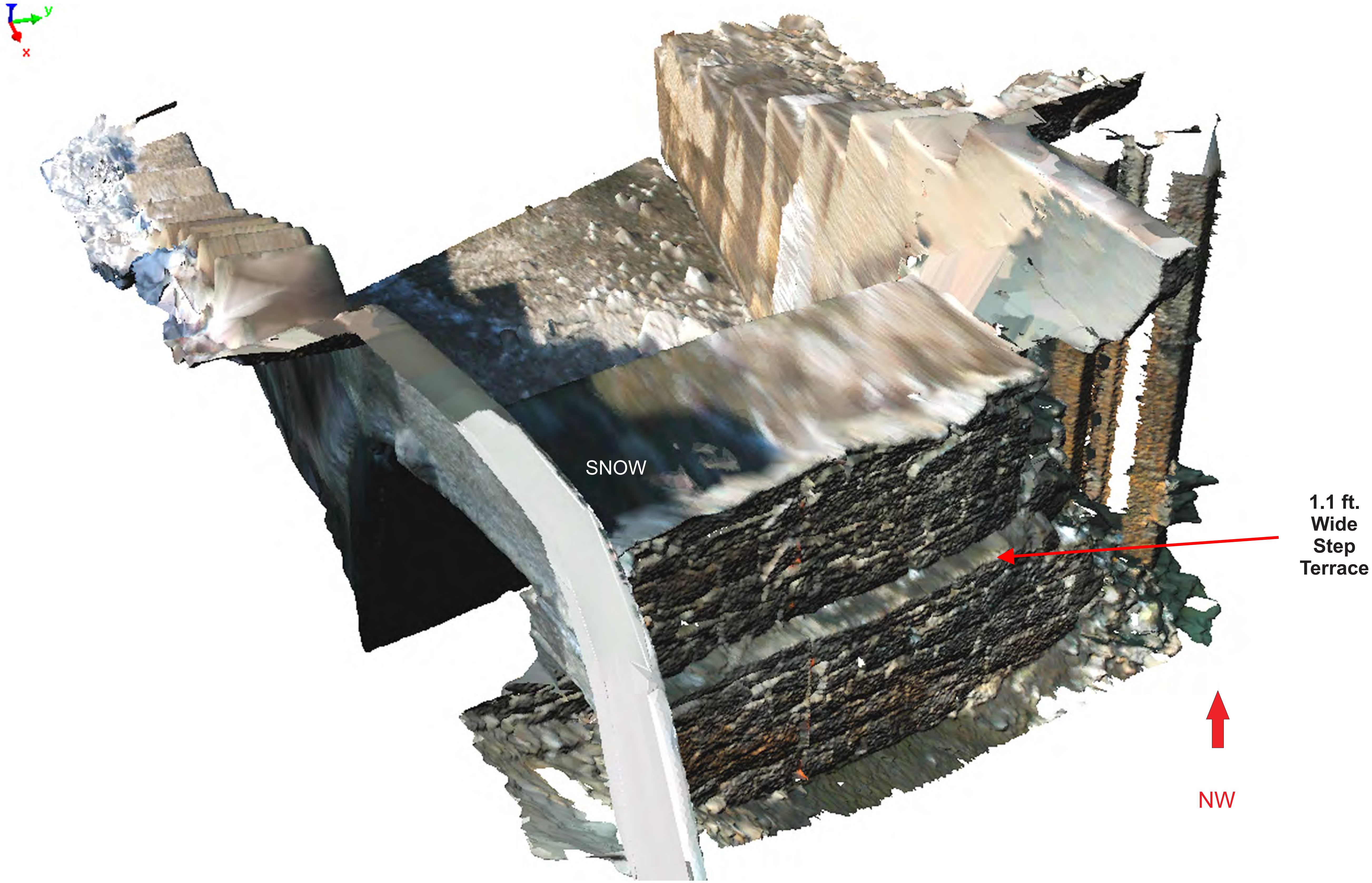


Figure 52: 3D color LIDAR view looking northwest at exposed eastern cut stone face of historic Furnace Falls Dam showing 1.1 ft wide step terrace 6 feet below the top of the spillway.

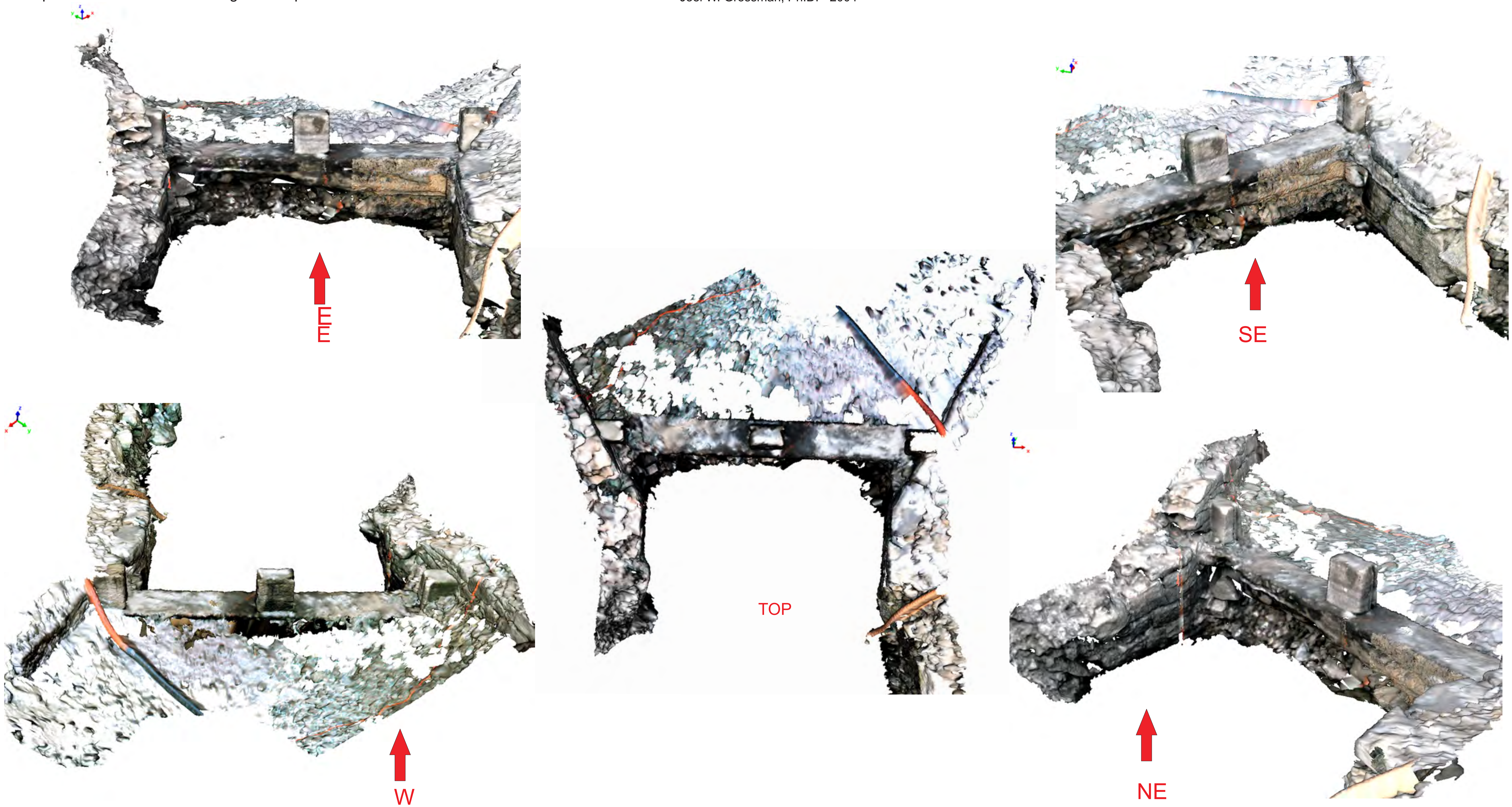


Figure 53: 3D color LIDAR scans of post-1927 cement Weir and earlier, 1874, cut stone wing walls of former arched bridge at Furnace Falls Pond.

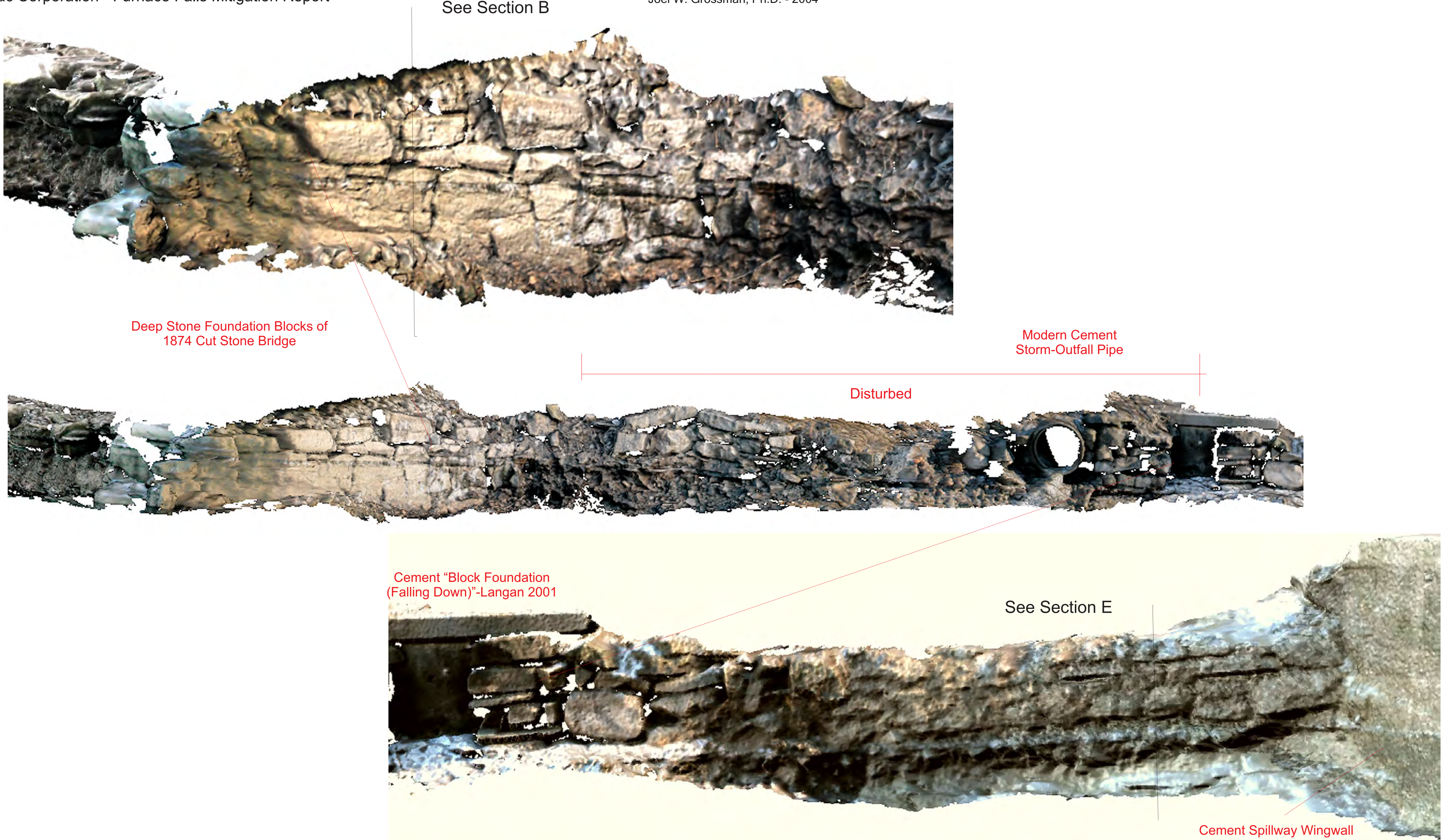


Figure 54: 3D color LIDAR scans of three sections of the south embankment of Furnace Falls channel: 1) The eastern end (top), near the former 1874 cut stone bridge, contained large, seven foot deep, stone blocks of the former bridge abutment between elevations 827 and 835+ feet. 2) The center section was disturbed by modern, ca. 1960, intrusions associated with the installation of a storm sewer outfall pipe and cast cement utility box. 3) The western 30 ft. section (right), adjacent to the cement Spillway wing wall, consisted of a three-course, five foot high, line of cut stone blocks between elevations 828 and 834 ft.

Figure 31: Rolleimetric film-based macro flat field photograph of southern profile of Furnace Falls Dam exposed to 11 feet (el: 819 ft.) below lip of spillway(@ 830 ft.). Note imbedded calibration marks for photogrammetric image rectification. *Photo by Joel W. Grossman, Ph.D.*

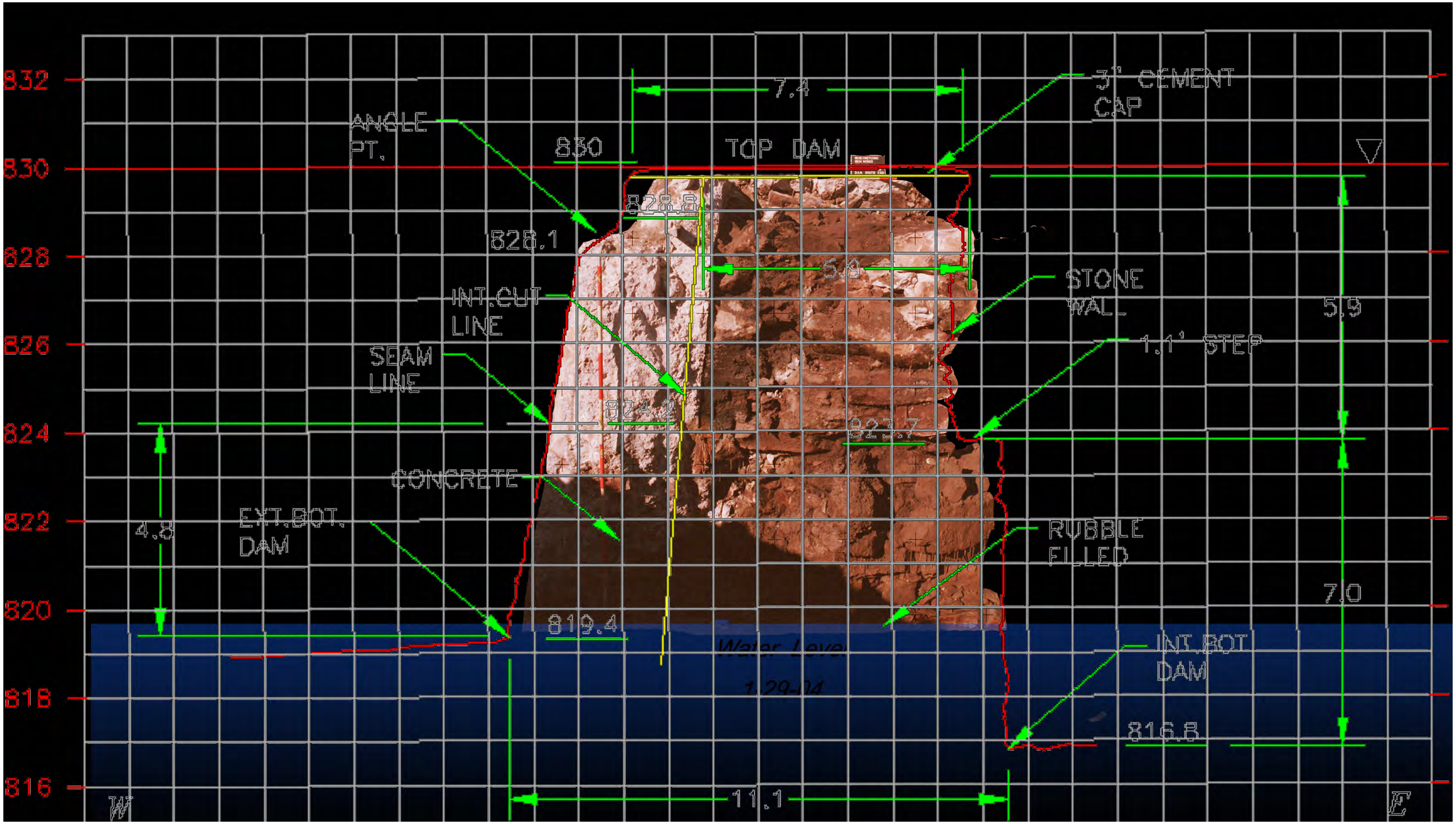


Figure 32: Digital composite of Rolleimetric film-based metric photo of south end of 1830 era cut stone dam, scaled and overlaid onto LIDAR derived elevation and dimension profile measurements relative to water level on January 29, 2004. *Rolleimetric photo and composite by Joel W. Grossman, Ph.D. All Rights Reserved c2004.*

Figure 27: Panoramic composite, looking west at the exposed eastern face of the 1830 era Furnace Falls dam, taken by integrated, computer controlled, Nikon digital camera mounted on the Rielg LIDAR scanner. The “seamed” digital picture, which shows the scanner’s field of view (what it “saw”), was matched, pixel by pixel, to the 6 mm. precise LIDAR scanner-derived coordinate points, to render the true color 3D data captures of the formerly submerged dam. Overlapping digital photo series were taken with flash after sunset during final LIDAR scan of dam on January 21, 2004. Temperature range: 10 - 14 degrees F.

Figure 26: Digital macro photograph of east facade of Furnace Falls cut stone dam taken with natural light on afternoon of LIDAR scan, January 21, 2004. Note iron oxide stains and lighter band denoting depth of historic channel sediments.

Figure 28: a) Digital photo looking southwest at eastern cut stone face and 6 ft high square finished northeast corner of the cut stone dam suggesting a former lower sluiceway(@ ca 824 ft. el) immediately north of the cement, or Singer, Spillway; b-d) Location map and structural details from the post-1840 Retaining Wall of the Musconetcong Iron Works supporting the Canal Spur Reservoir into the Foundry from the Morris Canal. The masonry of the 16 ft. high Foundry Retaining Wall has dry laid stonework comparable to that encountered in the cut stone dam. Note rust colored iron oxide stains at corner of Retaining Wall from former blast furnaces.

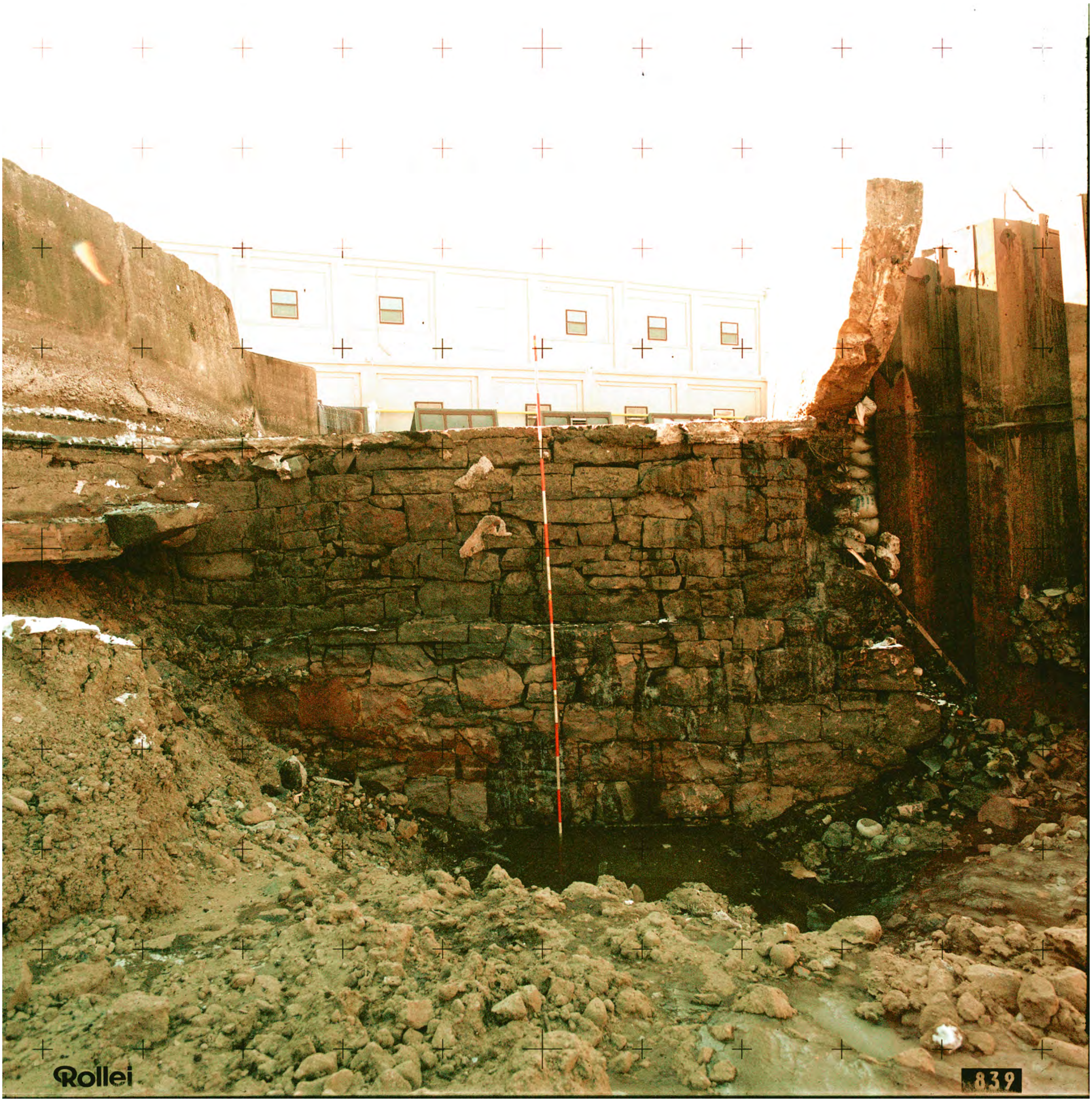


Figure 24: Rolleimetric flat field film image, looking west, at eastern face of Furnace Falls Dam exposed to16 feet below spillway lip, January 21, 2004. *Photo by Joel W. Grossman, Ph.D.*

JOEL W. GROSSMAN, Ph.D.

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PROFESSIONAL PROFILE:

- **Experienced Educator, Public Speaker and Author: North American, South American/Andean Archaeology, Environmental Archaeology, Historical Archaeology of the Northeast US/New York, Archaeological Method &Theory, Field and Laboratory Techniques in Archaeology.**
- **Strong Research, publication and project management record in the archaeology, ethnobotany and ethnohistory of Andean South America and the Northeast United States.**
- **Internationally recognized for the innovative planning and mobilization of multi-disciplinary applied technology solutions for logistically challenging archaeological contexts.**
- **Expert in the Design and Implementation of training programs in archaeological field and laboratory methods and the use of geospatial (Historic-GIS) strategies in land use history and historic preservation.**
- **Expert in the cultural geography, economic history & human ecology of Dutch New York.**

PROFESSIONAL ACCOMPLISHMENTS& EXPERTISE:

Directed over 30major archaeological expeditions and emergency rescue field operations(data recovery and mitigation planning solutions)for national and international agencies throughout the US and Latin America.

Directed the archaeological study of early metal technology and the economic origins of non-market Andean highland economies in Peru; early man sites in California and the eastern US, and important 17th, 18th and19thcentury Colonial and Civil War-era sites in New York and New Jersey.

Developed multi-agency(NJ Meadowlands Commission, the USEPA, USA Army Corps, New Jersey DEP, and NOAA) environmental management plan based on the innovative use of historic GIS and 3D terrain modeling to project archaeological sensitivity within the now submerged New Jersey Hackensack Meadowlands.

Planned and directed the first archaeological all-weather terrestrial and marine HAZMAT surveys and excavations of chemically and radioactively contaminated "Superfund" sites in North America.

Directed critical large-scale archaeological mitigation projects in New York City-including the discovery of the original 17thCentury Dutch West India Company settlement in Lower Manhattan, and New York's first municipal Almshouse under City Hall Park.

Trained international teams in the use of advanced applied technology in archaeological field and laboratory procedures.....in Peru, Mexico, Brazil, the Caribbean, Hungary and Russia.

WORK HISTORY:

Visiting Scholar's Program	PACE UNIVERSITY	2012
Visiting Scholar's Program	NETHERLANDS INSTITUTE OF HERITAGE	2009
Consultant–Dutch Archaeology	MUSEUMOFCITYOFNEW–HENRY HUDSON EXHIBIT	2009
Senior Archaeological Advisor	NJMEADOWLANDSPLAN, USACE-HUNTER RESEARCH	2005-2006
Archaeological Project Director	EMERGENCYDAMREMEDIATION,STANHOPE,NJ.	2002-2004
Director of Applied Technology	R G A ARCHITECTS AND PLANNERS,INC,N.Y.	1997-2001
President/ Principal Scientist	GROSSMAN AND ASSOCIATES,INC.,N.Y.	1986-1996
Principal Archaeologist/Director of New York Office	GREENHOUSECONSULTANTS,INC.	1982-1985
Founder & Director	RUTGERSARCHAEOLOGICALSURVEYOFFICE,RUTGERS	1976-1981

EDUCATION:

Ph.D. University of California, Berkeley;Dissertation:*EarlyCeramicCulturesofAndahuaylas,Apurimac,Peru.*
B.A. University of California, Berkeley

AWARDS AND APPOINTMENTS: Fulbright-Special Career, Ford, NSF& OAS-Andres Bello fellowships,; elected Fellow-Explorers Club(1999); Institute of Andean Studies; Hudson River Environmental Society; Dutch Visiting Scholars program of the Netherlands Institute of Heritage and invited speaker for the 2009 Quadcentennial Henry Hudson celebrations, Exhibit and Program Advisor in Dutch Archaeology: New Amsterdam History Center; Museum of the City of New York.

LANGUAGES: Spanish

JOEL W. GROSSMAN, Ph.D.

SELECTED PUBLICATIONS & TECHNICAL STUDIES

2015	(with Lucille Johnson and Dorothy Peteet) The Archaeology of Little Wood Creek: New Chronometric Evidence. *Archaeology of Eastern North America* , Vol. 43.,pp. 173-198
2013	The Waywaka Gold: New Chronometric Evidence. *AndeanPast*.Vol11, pp123-138.Cornell University Latin American Studies Program, Ithaca, N.Y.
2013	A Low Status Late Intermediate Offering Deposit, Andahuaylas, Apurimac Peru. *Andean Past* .Vol11, pp283-290,Cornell University Latin American Studies Program ,Ithaca, N.Y.
2011	Chapter8: Archaeological Indicesof Environmental Change and Colonial Ethnobotanyin17thCentury Dutch New Amsterdam. In: *The Environmental History of the Hudson River: Human Uses that Changed the Ecology, Ecology that Changed Human Uses*.pp.77-122.Ed.Robert E. Henshaw. State University of New York Press, Albany, NY.
2010	(By Tamara Stewart with editorial input by JWG-Highlights Dr. Grossman's Superfund work at West Point Foundry) "ExcavatingHazardousSites",Vol.14, No.1,pp38-42. American Archaeology, Albuquerque, NM.,Spring2010.
2008a	Future of Archaeology in21st Century:Human-LandscapeInteractions.In:*EncyclopediaofArchaeology*.Pearsall,D.(ed.). Vol.2,pp.1458-1476.Elsevier/Academic Press, Oxford, England.Vol.2, pp.1458-1476.
2008b	Inter-Regional Studies: Archaeology of Toxic and HazardousEnvironments.In: *Encyclopedia of Archaeology*. Pearsall, D. (ed.).Vol.3,pp.2134-2156.Elsevier/Academic Press, Oxford, England.
2006	Cultural Resource Investigation of Ten Sites in the Hackensack Meadowlands Restoration Project, Hudsonand Bergen Counties, New Jersey. Prepared for the US Army Corps of Engineers, Region II, New York by Hunter Research with contributions and recommendations by Joel W. Grossman, Ph.D. and Dorothy Peteet, Ph.D., Lamont Doherty Earth Observatory. Contract No. DACW51-01-D-0018 Delivery Order No.0046.
2004	The Archaeology of Furnace Falls: A Mitigation Report on the Use of GIS,GPS& LIDAR for the Definition and Documentation of Furnace Falls Dam, Spillway, Weir& Channel. Prepared for the NJDEP & Compac Corporation, Netcong, NJ,NJDEPAcc.No.MULTC541a.
2003	From Raritan Landing to Albany's Riverfront: The Path Toward Total 3DArchaeological Site Recording. InFisher, Charles, Ed. *People, Places and Material Things: Historical Archaeology of Albany,NewYork*.Chapter15: Battles and Breakthroughs. New York State Museum Bulletin499,pp.167-186.TheUniversityofTheStateofNewYork,TheState Education Department, Albany, NY.
2002	Joint Engineering and Archaeological Mitigation Plan for the Furnace Falls Pond Dam, Weir, Spillway and Channel, Stanhope/Netcong Morris and Sussex Counties,NewJersey.PreparedforCompacCorporation,Netcong,NewJersey. September1,2002.NJDEPAcc.No.MULTC541.
1997	AppliedTechnologyinArchaeologicalInvestigation.U.S.ArmyEnvironmentalCenter,AberdeenProvingGround, Maryland,139pp.
1996a	ArchaeologicalandHistoricalSensitivityEvaluationoftheU.S.RadiumFacility– Tasks1,2,3,4&9,CityofOrange,Essex County, New Jersey. Draft Final Report–Revision II Prepared forMalcolm Pirnie, Inc. & USEPA: Subcontract No. ARCS- C-018.September,1996.
1996b	ThePrehistoricandHistoricArchaeologyofWestBranchDam#1,Carmel,NewYork:Stage1A/1BFindingsand Recommendations.PreparedforJohnG.WaiteAssociatesfortheNewYorkDEPaspartofthe West Branch Dam Remediation,February,1996.
1995	"HistoricandCulturalResources"inDraftEnvironmentalImpactStatementontheSpecialAreaManagementPlan(SAMP) fortheHackensackMeadowlandsDistrict,NJ.PreparedforCDM,theUSACE,NOAA,USEPA,NJDEPandthe MeadowlandsCommission.June1995.
1994a	"High Caliber Discovery", FederalArchaeology.Vol.7,No.2pp.38-43,Summer1994.
1994b	The Role of Espionage and Foreign Intelligence in the Development of Heavy Ordnance at the West Point Foundry, Cold Spring, New York. In: Look to the Earth: The Archaeology of the Civil War. C.Geier, Editor, Universityof Tennessee Press.
1994c	Hackensack Meadowlands Archaeological and Historical Sensitivity and Impact Evaluation, Vols. I-II. Prepared as part of the Multi-Agency Special Area Management Plan(SAMP) for the USACE, NOAA, USEPA, NJDEP and the Meadowlands Comission

1994-1978 "Archaeology:TheWesternHemisphere,"Annual Review of New World Discoveries. Editor/Author, Encyclopedia Britannica Yearbook(Chicago).

1993a Stage II Archaeological Data Recovery and Mitigation Results of the Investigation of the Historic Coal Gasification Works at theNiagara Mohawk Power Corporation site, Saratoga Springs, Saratoga County, NewYork. Prepared for the Niagara Mohawk Power Corporation and the USEPA, Region II.

1993b The Archaeology and Economic History of the Civil War Era Workers' Housing Complex at West Point Foundry, Cold Spring New York.(Grossman et al.).USEPA and USACE, Region II, New York, NY.

1992a A Stage I Archaeological and Historical Sensitivity Evaluation of Foundry Cove and the Cold Spring Waterfront [GIS, marine geophysics and sub-bottom sedimentation & trace element coring of Foundry Marsh],USEPA, Region II.

1992b Stage IA Archaeological and Historical Sensitivity Evaluation of the Hackensack Meadowlands, New Jersey. Prepared for the Hackensack Meadowlands Development Commission, NJDEP & USEPA.

1991a The Archaeological Discovery and Excavation of R.P. Parrott's Civil War Era Gun Testing Facility at WestPoint Foundry. Prepared for the USEPA, Region II.

1991b "The Buried History of City Hall Park: The Initial Archaeological Identification, Definition and Documentation of Well-Preserved18th.CenturyDeposits and the Possible Structural Remains of New York City's First Almshouse."NYC Department of General Services, New York, NY.

1991c Excavation and Analysis Results of Archaeological Investigations at Mediania Alta(L-23)and Vieques (L-23),Loiza, Puerto Rico. Puerto Rico Aqueduct and Sewer Authority (PRASA),San Juan, P.R.

1991d StageIA Cultural Resource Survey of the Montclair, WestOrange and Glen Ridge Study Areas, NewJersey.[U.S. RadiumDumpAreaSuperfundinvestigation],CDMFederalProgramsCorporation&USEPARegionII.

1990 The Excavation, Analysis and Reconstruction of Transitional Period, Late Woodland Period, and Colonial Occupationsat the Little Wood Creek Site, Fort Edward, Washington County, New York. USEPA and the Washington County Sewer Authority,USEPAProj.-C36-1305-01.

1987 The Waterfront of Colonial New York: An Intensive Archaeological Sensitivity Study of Potential Surviving Archaeological Remains within the Defined South Ferry Development Parcel. Prepared for the Zeckendorf Corporation, NewYork,NY. Vol. I:76pp,Text& Plates; Vol. II: Map Reconstructions & Geospatial Survivals.

1985 The Excavation of Augustine Heerman's Warehouse and Associated 17th Century Dutch West India Company Deposits: The Broad Financial Center Mitigation Final Report. 3 vols., Prepared for the Landmarks Preservation Commission, NewYork, New York, by Greenhouse Consultants, Inc.

1983 Demographic Changes and Economic Transformations in the South Central Highlands of Pre-Wari Perú. *Nawpa Pacha*, Number 21, pp.45-126. Institute of Andean Studies, Berkeley, California.

1982a Seeing Underground: the Feasibility of Archaeological Remote Sensing in Coastal and Highland Peru. Prepared for the Instituto Nacional de Cultura, Lima,Peru. UNESCO, OAS, & the Andres Bello Fund.

1982b Raritan Landing: The Archaeology of a Buried Port. Rutgers Archaeological Survey Office, New Brunswick ,New Jersey. Prepared For the USEPA-Region II and the Middlesex County Sewer Authority.

1980a Defining Boundaries and Targeting Excavation with Ground-Penetrating Radar: the Case of Raritan Landing. *Environmental Impact Assessment Review*,Vol.1,No.2, Plenum Publishing Corporation

1980b The Status and Potentials of Predictive Surveys in New Jersey. In: *New Jersey State Plan for Historic Preservation*. Trenton: State Historic Preservation Office.

1977 (with David A. Fredreickson) A San Dieguito Component at Buena Vista Lake, California. *The Journal of California Archaeology*,Vol.4.,No.2.Pp.173-190.

1972 An Ancient Gold Worker's Tool Kit. *Archaeology*,Vol.25, No4, pp.270-275.

RECENT INVITED CONFERENCE PAPERS

2013 "Early Foods and Medicines of 17th Century New Amsterdam: Cross-cultural Plant Population Exchange and Environmental Change in the Lower Hudson Valley" .Invited paper for the *Ecology of New York Cit y:Organisms,Environment and History* conference. Sponsored by the Columbia University Seminar on Population Biology. ColumbiaUniversity,New York. April 20, 2013.

2010 "The Archaeology of Environmental Change in the NY/NJ Harbor Estuary."Sponsored by the *Hudson River Foundation* in cooperation with the *New York/NewJerseyHarborEstuaryProgram*.NewYork,NY.March24,2010.

2009a "Archaeological Indices of Environmental Change and Colonial Ethnobotany in 17th Century Dutch New Amsterdam". Hudson River Environmental Society (HRES) Conference: *Environmental History of the Hudson River*. Hyde Park, New York. November 6, 2009, Peekskill, NewYork.(SUNY Press) 2009b

2009b "New Insights into the Material Culture of 17th century New Amsterdam". Invited paper for the conference."Four Centuries of Dutch-American Relations, Sponsored by AWAD(the Atlantic World and the Dutch),the Netherlands Institute for Heritage, and the National Archives of Holland, Amsterdam. October15-16,2009.

2009c "History vs. Natural Disaster: Applied Geospatial Solutions for Emergency Discovery and Documentation in Archaeology". Long Island GIS Users Group, Brookhaven National Laboratories, Brookhaven ,New York May.

2008 "The Colonial Cartography and Buried Landscape of 17thCentury New Amsterdam."Invited paper before the Annual Meeting of the North East Map Organization (NEMO), Chester, Vermont. June5-6, 2008.

2007 "Archaeology, Technology and Environmental Change". Invited paper before the UN-NGO Workshop:" From the Cityto theCountryside:ClimateChangeImpactontheBeijingOlympicsandClimateImpactonRuralDevelopment".60thAnnual UNDPI/NGO Conference:"Climate Change :How It Impacts Us All," 5-7September2007.UnitedNations,NewYork